GROUP A: PROJECT MANAGEMENT

A1 – Title and Approval

MODELING QUALITY ASSURANCE PROJECT PLAN

for

Technical Support for West Virginia Ionic Toxicity TMDLs

Contract EP-C-17-046, Task Order 0015
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The following persons have reviewed this Modeling Quality Assurance Project Plan (QAPP) for Technical Support for West Virginia Ionic Toxicity TMDLs. Should any revisions, amendments, or other changes be made to this plan they will be distributed to the persons named below, those named in the plan distribution list, and to any other technical staff or subcontractors working on the project, by the EPA Task Order Contracting Officer's Representative (TOCOR) and Tetra Tech Task Order Leader (TOL) or their designee(s). Final approval of this document is made by the EPA Designated Approving Official (DAO).

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Abbreviations and Acronyms

AGWETP	fraction of remaining potential evapotranspiration that can be satisfied from active ground-water storage
AGWRC	basic ground-water recession rate
BASETP	fraction of the remaining potential evapotranspiration that can be satisfied from base flow
CAI	climatologically-aided interpolation
CAIR	Clean Air Interstate Rule
CASTNET	Clean Air Status and Trends Network
CEPSC	Interception Storage Capacity
CSAPR	Cross-State Air Pollution Rule
DDL	diffuse double layer
DEEPFR	fraction of ground-water inflow that flows to inactive ground water
DEM	digital elevation models
DMR	WVDEP Division of Mining and Reclamation
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
GIS	geographical information system
HSG	hydrologic soil group
HSPF	Hydrologic Simulation Program – FORTRAN
HRU	Hydrologic Response Unit
HUC	hydrologic unit code
INFILT	index to the infiltration capacity of the soil
INTFW	interflow inflow
IRC	interflow recession constant
LA	Load Allocation
LSPC	Loading Simulation Program in C++
LSUR	length of the overland flow plane
LZETP	lower-zone evapotranspiration
LZSN	nominal capacity of the lower-zone storage
MDAS	Mining Data Analysis System
MINTEQA2	Metal Speciation Equilibrium for Surface and Ground Water
MINEQL	Chemical Equilibrium Modeling System
MOS	margin of safety
NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Center
NED	National Elevation Dataset
NLCD	National Land Cover Dataset
NLDAS-2	North American Land Data Assimilation System
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NSUR	Manning’s Roughness of the land surface

PHREEQC	Computer Program for Speciation, Reaction-Path, Advective Transport, and Inverse Geochemical Calculations (pH-REdox-EQuilibrium Equations)
PM	project manager
PRISM	Parameter-Elevation Regressions on Independent Slopes Model
QA	quality assurance
QAO	quality assurance officer
QAPP	quality assurance project plan
QC	quality control
SC	specific conductance
SLSUR	slope of the overland flow plane
TDS	total dissolved solids
TH	total hydrogen
TMDL	total maximum daily load
TOCOR	Task Order Contracting Officer's Representative
TOL	Task Order Leader
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UZSN	nominal capacity of the upper-zone storage
WASP	Water Quality Analysis Simulation Program
WLA	Wasteload Allocation
WPD	Watershed Protection Division
WVDEP	West Virginia Department of Environmental Protection

1.0 INTRODUCTION

1.1 Background, Study Area, and Project Objectives (A5, A7)

The U.S. Environmental Protection Agency (EPA) Region 3 is coordinating with the West Virginia Department of Environmental Protection (WVDEP) to develop Total Maximum Daily Loads (TMDLs) in waterbodies where ionic toxicity has been identified as a contributing cause of biological impairment. To establish a TMDL for waterbodies identified as biologically impaired on West Virginia's Section 303(d) list, WVDEP identifies the cause of the biological impairment, i.e., the type of pollutant that will be allocated in the TMDL(s) to address the biological impairment, through a stressor identification procedure completed during the TMDL development phase. In the course of work on previous TMDLs, WVDEP identified certain waters as biologically impaired due to ionic toxicity. Ionic toxicity results from the presence of excessive amounts of dissolved solids (e.g., mineral salts) in a waterbody and can cause biologic impairment by adversely impacting aquatic life. While WVDEP has historically had sufficient information regarding instream ionic toxicity levels and their effects on benthic macroinvertebrates to identify ionic toxicity as a cause of biological impairment in these waters, WVDEP lacks sufficient information about which particular dissolved solid(s) (e.g., sulfate, bicarbonate, magnesium, chloride, potassium, etc.) caused the ionic toxicity, and their associated impairment thresholds and their sources, to establish a defensible TMDL.

In the fall of 2010, EPA and WVDEP began a project to develop a pilot TMDL for ionic toxicity in streams in the Upper Kanawha Watershed. EPA and WVDEP collaborated on workgroups focused on TMDL planning, endpoint development, model development, and treatment technology. During the pilot project, a TMDL endpoint was proposed for specific conductance and a model was developed. WVDEP ended participation in the pilot project in April 2012, citing state legislation that required the development of new assessment methodology to determine biological impairment. Since that time, WVDEP has developed hundreds of pollutant TMDLs that address biological impairment caused by stressors other than ionic toxicity.

EPA and WVDEP are interested in developing ionic toxicity modeling tools in a pilot watershed where TMDL development is currently occurring. As part of its Watershed Management Framework approach to TMDL development, WVDEP is developing TMDLs in the Lower Guyandotte River Watershed for other pollutants (fecal coliform bacteria, total iron, and selenium) with anticipated completion by February 2021. Waters from the Lower Guyandotte River Watershed will be included in the pilot model development.

An appropriate model has been selected to address waters impaired by ionic toxicity. A detailed discussion of the model selection process and requirements is provided in Section 2.3. EPA shared previous work products, including a TMDL modeling framework developed using WVDEP's Mining Data Analysis System (MDAS) as a starting place for model selection deliberations. Modeling recommendations considered the availability of data and existing model set up for previous and current TMDL project areas. Using literature reviews or other technical analyses, Tetra Tech characterized potential general sources of ions, including mining, wastewater treatment plants, straight pipes, etc. to incorporate into the modeling framework. The characterization of hydrologic alterations due to mining and potential similarities to the hydrology of heterogeneous materials (e.g. glacial till, etc.) were explored. Model recommendations were provided based on the complexity of the pollutant loading dynamics, sources, data availability, etc. The model recommendations are compatible with WVDEP's current modeling platform, so future ionic toxicity modeling can make use of the hydrology calibrations already completed for previous TMDL project areas.

Using MDAS, Tetra Tech will develop the pilot model for selected biologically impaired streams in the Lower Guyandotte River Watershed. A list of 24 waters to be included in the pilot model development was selected by WVDEP and reviewed and approved by EPA (Table 1). Recent data and modeling information supplied by WVDEP will be incorporated into the pilot ionic toxicity model. Model development includes model calibration and validation, TMDL allocation scenarios, and a draft and final version of the modeling report.

Table 1. Lower Guyandotte River Watershed Waters Identified as Impaired by Ionic Toxicity.

STREAM_NAME	ANCODE
Russell Creek	WVOG-1
Davis Creek	WVOG-3
Edens Branch	WVOG-3-0.5A
Big Ugly Creek	WVOG-38
Left Fork/Davis Creek	WVOG-3-A
Right Fork/Davis Creek	WVOG-3-B
Rockhouse Fork	WVOG-44-D
Limestone Branch	WVOG-48
Ed Stone Branch	WVOG-49-A
Trace Fork	WVOG-49-D
Perrys Branch	WVOG-49-E-1
Crawley Creek	WVOG-51
Fowler Branch	WVOG-51.5
South Fork/Crawley Creek	WVOG-51-G.5
Godby Branch	WVOG-53
Rocky Branch	WVOG-55
Peach Creek	WVOG-64
Mud River	WVOGM
Merrick Creek	WVOGM-1
Tanyard Branch	WVOGM-1.5
Cyrus Creek	WVOGM-2
Sugartree Branch	WVOGM-47
Stanley Fork	WVOGM-48
Ballard Fork	WVOGM-49

Under a parallel task, a separate workgroup is evaluating potential ionic toxicity endpoints. That group will evaluate the appropriateness and utility of targeting individual ions and/or a cumulative state variable (e.g. total dissolved solids). The modeling products will specifically address the recommendations of that group.

The modeling report will be broken up into milestones to allow for review and comment by WVDEP and EPA on the model development. The first milestone will include model background, such as model set-up and watershed characteristics. The second milestone will present the calibrated and validated model, including model error statistics and graphical representations of model output. The third milestone will present a minimum of two TMDL allocation scenarios. This milestone will include graphical representations of endpoint/water quality standard attainment. The fourth milestone will include discussion of TMDL requirements, including critical conditions, seasonal variability, margin of safety, and conservative assumptions.

The objective of the modeling is to develop an assessment tool that considers existing watershed conditions, including land cover and management practices throughout the watershed and represents point sources, including mining, straight pipe and wastewater treatment plants, among others. The model should capture incoming loads from the entire drainage area to provide a robust modeling framework to properly simulate the hydrology, hydrologic alteration, flow routing, hydro-geochemical reaction, and individual ions' fate and transport in the system. Once calibrated, the modeling system will be able to represent the linkage between the sources in the watershed and the instream response to ionic concentrations, allowing comprehensive TMDL scenarios to be evaluated.

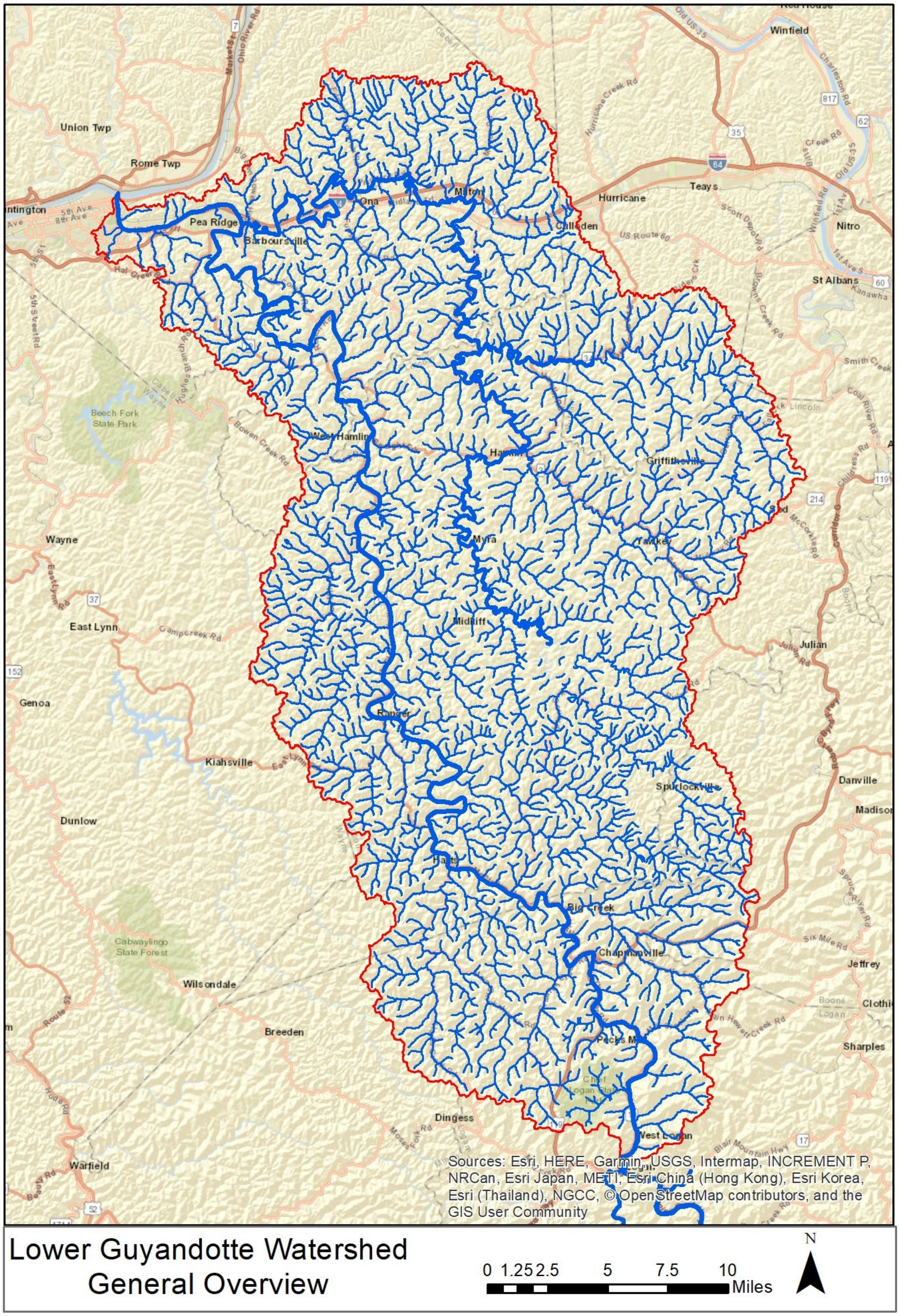

Figure 1. Lower Guyandotte River watershed.

This QAPP provides a general description of the modeling quality assurance (QA) system and associated analytical work that Tetra Tech will perform for the project, including following data quality objectives (DQOs) and quality control (QC) procedures. This QAPP also addresses the use of secondary data (data collected for another purpose or collected by an organization or organizations not under the scope of this QAPP) to support model development and application. The QAPP is based loosely on the format and content recommendations in *EPA's Guidance for Quality Assurance Project Plans for Modeling*, (USEPA, 2002), *Guidance for Quality Assurance Project Plans for Water Quality Modeling Projects* (USEPA, 2016a), and, where reasonable, the plan includes linkage to EPA's QAPP requirements document *Requirements for Quality Assurance Project Plans, EPA QA/R-5* (USEPA 2001) at the associated section headers.

1.2 Project Plan Overview and Timeline

TMDL model development for the Lower Guyandotte watershed is a complex project involving development and testing of complex tools to assess existing conditions and evaluate allocation scenarios. Due to the number of potential pollutants to be assessed, the complex fate and transport of these pollutants, and the data and knowledge gaps to surmount in building the model, there is a high degree of uncertainty in the project schedule. As such, this QAPP describes all the key elements of the model development plan that can be determined at this time, including management objectives, model state variables, model framework selection, data availability and quality, selected time frame for modeling analysis, and documentation of model quality. However, due to the complexities of the project, this QAPP cannot answer all model development planning questions at this time. In some cases, the document identifies a specific modeling challenge and defers decisions on how to address the challenge until more information is available. One notable example is the selection of an appropriate endpoint or multiple endpoints. The modeling setup will keep the maximum flexibility to include most relevant ions in the simulation. The model calibration and validation will be targeted to make model simulations matching monitoring endpoint(s) records, once the endpoint(s) is selected. The currently anticipated sequence of events and project timeline is shown below in Figure 2. Events pertaining to this QAPP are addressed in Task 2.3, 2.4, and 2.5. As noted above, water quality calibration is contingent upon final ionic toxicity TMDL endpoint(s) to be determined simultaneously to model development. Endpoint development (Task 2.2) is anticipated to be complete by October 2020.

Model development tasks will proceed from model configuration to hydrologic calibration, followed by water quality calibration. Once the model is calibrated and validated, the model will be used to develop allocations that attain the endpoint(s) selected for watersheds. The model configuration will leverage WVDEP and Tetra Tech's ongoing Lower Guyandotte TMDL work for other pollutants. The subwatershed delineation, land use-land cover distribution, meteorological data, source identification and characterization, and hydrological parameterization can be used to configure the selected model for ionic toxicity. The model will then need to be configured for the pollutant(s) addressed by the TMDL based upon the selected endpoint(s).

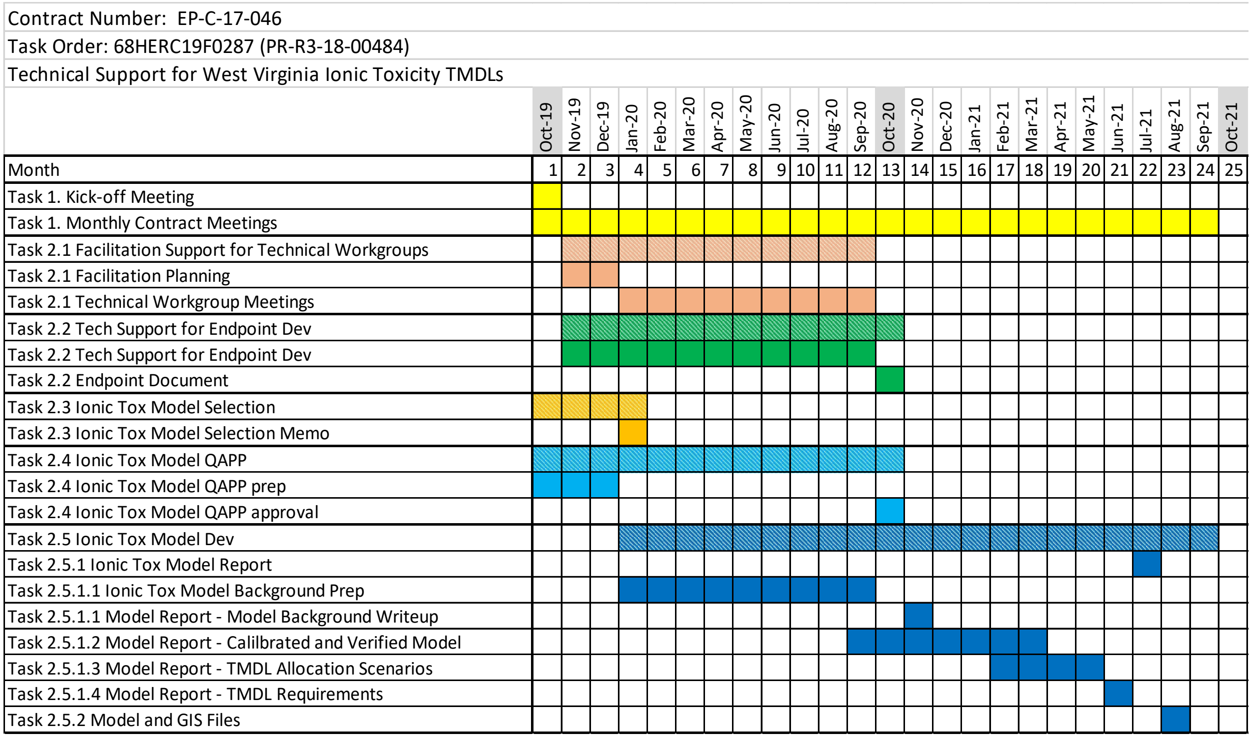

Figure 2. Estimated Ionic Toxicity Model Development Timeline

Streams in which ionic toxicity is identified to be a significant stressor typically have a strong presence of dissolved ions such as sulfate, bicarbonate, chloride, and elevated conductivity. Other dissolved ions such as sodium, calcium, potassium, and magnesium are required to be analyzed as well. Potential sources of ions, both natural and anthropogenic, include active and legacy mining activities (and associated ion additions for metals and pH wastewater treatment operations), stormwater from developed lands, oil and gas operations, wastewater discharges, road salt application, agricultural management, and atmospheric deposition.

After configuration, hydrological calibration results for current Lower Guyandotte watershed TMDLs can be used as a starting point for ionic toxicity TMDL modeling. Under the C4 Lower Guyandotte TMDL project, Tetra Tech has already located and characterized the loading function mechanisms of watershed sources of several minor ions (e.g. ferric iron, aluminum, manganese) and will incorporate that information into the ionic toxicity TMDL modeling. The model representation of the unique hydrological processes of valley fills can also be explored with a combination of a rainfall-runoff process on land surface and soil matrix reservoir configuration. The objective will be to best simulate the concentration and loading of the variable of interest at low flow, mean flow, and storm peaks at representative water quality monitoring stations.

Model configuration may incorporate on-going data collection activities for source characterization or continuous stream monitoring. Those data will be incorporated into the model setup in the latter stages of the project. While ongoing data collection occurs, currently available data assessment can proceed and inform QAPP updates. Given the timeframe of the project it is anticipated that QAPP updates or addenda will be needed periodically during the project to make adjustments for development of future components, including the development of endpoint(s) and model scenarios. The goal of model development is to incorporate, to the extent feasible, all available data and knowledge of the system into the models, which will provide a comprehensive and defensible platform for TMDL development.

1.3 State Variable Selection (A7, B7)

Sections 303(d) and 305(b) of the Clean Water Act include requirements and responsibilities for states related to impaired waters and water quality inventories, respectively. Section 305(b) reports provide the framework for 303(d) impairment listings as a comprehensive inventory of water quality for surface waters within a jurisdiction and detail the assigned designated uses for each water body. Failure to meet the applicable water quality criteria for an assigned designated use generally results in that waterbody being included on the 303(d) impairment list for the violating pollutant and sampled media. The list of Lower Guyandotte River Watershed segments with biological impairment as a result of ionic toxicity is shown in Table 1 above. EPA and WVDEP coordinated on the final list of segments to be addressed through this modeling process

Nonetheless, based on previous studies of endpoint analysis for ionic toxicity, there are a number of state variables that can be factors in impacting ionic toxicity and all can be modeled. These state variables include:

- Total dissolved solids (TDS)
- Specific conductance (SC)
- Sulfates
- Chloride
- Sodium
- Calcium
- Potassium
- Magnesium
- pH
- Temperature
- Hardness and Alkalinity
- Bicarbonate
- Other Metals (Manganese, Iron, Aluminum)

Not all of the above state variables will be significant ion sources in all streams addressed by this project. In previous West Virginia TMDL development work, some deep mine discharges were identified as significant contributors of chloride while others were not. Drainage from subwatersheds with larger amounts of roads and impervious surfaces also caused elevated chlorides from de-icing activities while chlorides remained low in the drainages of undeveloped areas. Similar spatial variability is anticipated in this project.

Impairments for the “Other Metals” mentioned above often co-occur in streams with elevated ions but are generally not independently significant to ionic toxicity – i.e. chemical-specific concentrations greater than water quality criteria are often two or more orders of magnitude less than ion-problematic levels of sulfate, chlorides and bicarbonate constituents. Previous Tetra

Tech ionic toxicity work for West Virginia explored potential chemicals and reactions that may be important in the simulation of ion balances across the State and identified the important processes for different geological settings. Certain geologic formations produce high iron and aluminum hydroxides which drive geochemical reaction processes and the equilibrium pH in streams. The aforementioned metals are not likely to be significant factors in the simulation of the ion balances in most stream segments of the Lower Guyandotte watershed but may be more important if this work is extended to other watersheds where low-pH chemistry is prevalent.

Since the ion concentrations are impacted by other factors such as pH and possible adsorption/desorption to sediment, all related state variables need to be included in the model. As a parallel effort with endpoint analysis, the model development will keep the modeling results most flexible for the undecided endpoint target, outputting TDS/SC results and specific loading/concentration of listed ions at the same time for the selected hydro-geochemical model.

1.3.1 Available Data (A7, B9)

Data useful to the modeling effort includes physical/morphological data, and ambient water column data.

Water quality monitoring data provided by the WVDEP Watershed Assessment Branch include analytical results for concentrations of various constituents in the water column that are relevant to the processes being simulated in the model. Across the watershed, monitoring data were collected from 1970 to 2019, at 538 individual locations on the main stem and tributaries to the Lower Guyandotte River. Ion data that are most critical for model calibration and development in the tributaries are concentrated in the 2017/2018 pre-TMDL monitoring period. These results include:

- Total dissolved solids (TDS)
- Specific conductance (SC)
- Sulfates
- Chloride
- Sodium
- Calcium
- Potassium
- Magnesium
- pH
- Temperature
- Hardness and Alkalinity
- Other Metals (Manganese, Iron, Aluminum)

Stream and source water quality data (grab sampling) continues to be collected by WVDEP. Once compiled it will be provided to Tetra Tech. Additionally, WVDEP has deployed continuous conductivity monitors at key instream locations and at known significant ion sources. Deployment covers an extended period designed to capture seasonal variation from winter 2019/2020 through fall of 2020. This data will be especially useful in model calibration and source representation.

Another potential data source is the self-monitoring of outlets and instream locations required of permitted facilities (Discharge Monitoring Report data). In more recent time periods, self-monitoring for ionic toxicity constituents is being required of permittees. WVDEP will compile this information and provide it to Tetra Tech for consideration.

2.0 MODELING APPROACH (A5)

2.1 Goals and Objectives

The goals and objectives for the Lower Guyandotte River watershed modeling are to:

- Evaluate pollutant fate and transport and source control measures to effectively characterize existing loading and water quality conditions,
- Develop allocation scenarios that attain the selected endpoint(s) and support future TMDL development.

2.2 Model Conceptualization

A conceptualization of model elements of the Lower Guyandotte River watershed describes (natural and anthropogenic) sources of pollutants, chemical migration pathways, chemical reactions, equilibrium speciation of ions, TDS/conductivity calculation, pH calculation; see Figure 3.

2.3 Model Selection

The work described in this QAPP does not involve creating new simulation modeling software. Rather, it involves developing and applying the existing modeling framework of MDAS, as described further below. Following a description of the model requirements, a discussion of MDAS ability to meet these requirements is presented.

In selecting an appropriate technical approach for a comprehensive modeling system, technical, regulatory, and user criteria were considered. Models that are fully proprietary, models that are considered experimental or academic tools, and models that do not have a track record of successful performance on similar projects were eliminated from consideration. Technical criteria include the physical system in question, including watershed or receiving water characteristics and processes and the constituent(s) of interest. Regulatory criteria include water quality standards or procedural protocols. The following discussion details the considerations for each of these categories. Based on these considerations, a recommended framework is presented below to represent watershed and receiving water existing conditions and to evaluate pollutant source management scenarios that result in meeting numerical TMDL targets or endpoints.

Establishing the relationship between water quality and source loading is a critical component of modeling and determining the load reductions required to meet TMDL numerical targets. It allows for the evaluation of management options that will achieve various load reduction scenarios and attainment of water quality standards and designated uses. The link can be established through several techniques, ranging from quantitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that associate certain waterbody responses to flow and loading conditions. In addition, selection of a recommended technical approach also involves consideration of the technical, regulatory, and user criteria described above.

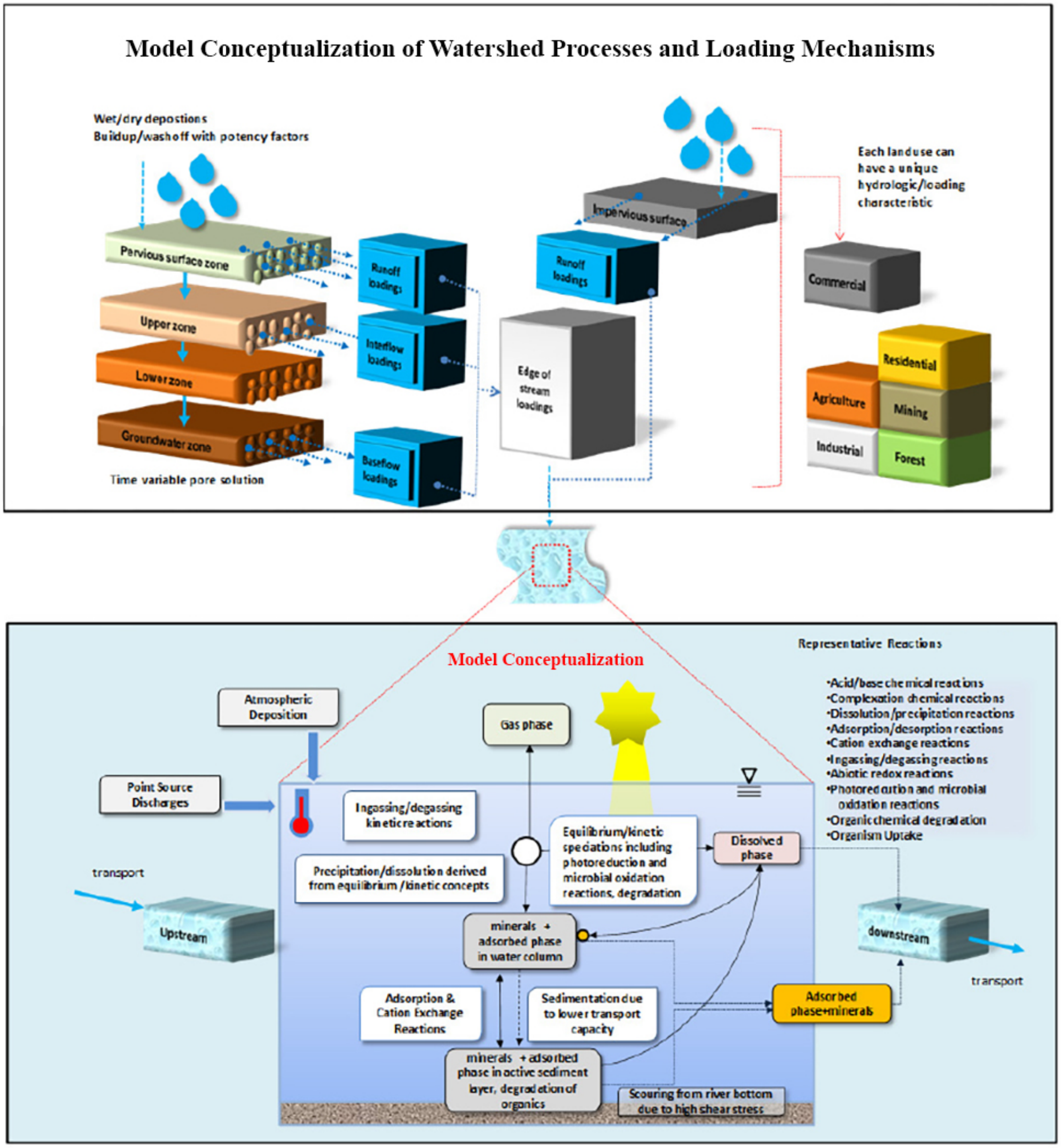

Figure 3. Watershed process and loading mechanisms.

A watershed model is essentially a series of algorithms applied to watershed characteristics and meteorological data to simulate land-based processes over an extended period, including rainfall-runoff, interflow, groundwater flow, flow routing, water temperature, and pollutant loadings. Watershed models often use build-up and wash-off representations of pollutants on the surfaces and can accommodate air deposition of pollutants. Many watershed models are also capable of simulating in-stream processes using land-based contributions as input. Watershed models can provide flow and pollutant loading to a receiving water model and can also simulate water quality processes within streams and lakes with relatively simple algorithms. A receiving water module will be used to calculate the ionic strength based on the equilibrium speciation in the water bodies based on the loadings from land sources.

The primary methods considered to represent the Lower Guyandotte River watershed included complex approaches that acknowledge the variety of pollutants and pathways in the system. The watershed model with in-stream hydrogeochemical components will be calibrated to characterize loadings from the Lower Guyandotte River watershed, ensuring that all major watershed sources and pathways are represented. The watershed model will estimate the relative pollutant contributions from multiple sources and can connect these contributions to the spatial distribution of contamination over time. The stream model will represent the transport and fate of pollutants via different pathways of chemicals in water columns. Modeling scenarios will be developed that link changes in management in the watershed to changes in loading and instream concentrations of contaminants.

The selected watershed model possesses the following capabilities to be a scientifically sound representation of the watershed loading and transport system and to be an advantageous management tool:

- Simulates hydrologic variations due to time variable weather patterns and the related transient saturation or unsaturated condition of the land surface/subsurface.
- Simulates time variable chemical loadings of metals and major ions from industrial, mining, urban, agricultural, and various natural pollutant sources in the watershed.
- Simulates interactions within a stream channel, specifically involving the evaluation of dynamic chemical speciation based on equilibrium calculations.
- Provides model results with a broad range of spatial and temporal scales.
- Evaluates source loading abatement and watershed management scenarios for water quality control.

The receiving water modeling is mainly aimed at representing the transport and fate of pollutants via different pathways of chemicals in streams and reaches. The selected modeling framework simulates the chemical speciation function of major aqueous ions (including but not limited to: chloride, sulfate, carbonate, sodium, potassium, magnesium, calcium, iron, aluminum, manganese) and chemical components (including but not limited to: TDS, conductivity, alkalinity, and acidity). The model will have the flexibility to fulfill TMDL regulatory requirements to address ionic toxicity based upon the endpoints being considered by the endpoint workgroup.

To simulate and attain realistic stream chemical conditions, the selected model will include a variety of chemical reactions to support various stream conditions affected by anthropogenic or natural sources:

- Chemical speciation
- Acid/base chemical reactions and pH simulations

- CO_2 gas degassing/ingassing kinetics in rivers and lakes
- Redox kinetics including potential photoreduction/microbial oxidation
- Kinetic mineral precipitation/dissolution
- Adsorption/desorption based on diffuse double layer (DDL) modeling
- Cation adsorption/desorption on clay surfaces represented by cation exchange capacity
- Aging/burial of active/inactive sediment layers related to sediment deposition from the water column and scour from the stream bed

To meet these criteria, the MDAS model is proposed for this project. MDAS is a continuous process-based model that dynamically simulates ion composition and time variable loadings and was updated specifically for a similar EPA project in 2012 (Tetra Tech 2012) for ionic toxicity pilot TMDL development in the Upper Kanawha watershed. All of the processes listed above were incorporated into MDAS during the 2012 update. Given the geochemistry of West Virginia streams, it is necessary to dynamically simulate pH because major ions include bicarbonate and sulfate, both of which are pH dependent. In addition, the dissolution of ferric and aluminum hydroxides can be significant drivers in watersheds with acid mine drainage.

The development of the TMDL watershed model will build on the previous MDAS watershed model development effort to simulate existing pollutant loading and water quality conditions and provide the basis for evaluating LAs and WLAs that meet selected endpoints. The MDAS model requires considerable data for configuration and calibration, providing the ability to represent complex pollutant interactions in detail. The model can also provide a variety of hydrologic and pollutant loading outputs. MDAS models chemical constituents effectively on a watershed scale by coupling simulation of complex loading processes to an advanced chemical loadings/reactive transport model. The stream components in MDAS include the dominant processes regulating the interactions and transport of major ions, metals, adsorbing materials, and mineral phases. Reactions between the water column and the streambed are represented along with the reactions governing the distribution of dissolved and particulate chemicals.

The chemical loadings from the land are transported to the adjacent stream reach via the hydrologic functionalities in MDAS. The in-stream transport is simulated in MDAS based on the complete-mix, unidirectional flow concept and kinematic wave flow routing method. MDAS's geochemical reactions within the channel are based on thermodynamics and chemical kinetics. MDAS's reactive chemical transport code is derived from the USEPA's MINTEQA2, and the equilibrium computational code for ionic speciation of cationic and anionic components in aqueous system originates from the MINEQL model. The kinetic reactions concepts are from either the chemical kinetics of USGS's PHREEQC model or published chemical kinetic reactions. The capabilities of a watershed model (LSPC/MDAS) were updated specifically to simulate the dominant ions that cause elevated specific conductance in WV streams. Significant research was performed by Tetra Tech prior to updating the model code to identify the most dominant geochemical reactions that are likely to occur given the various geologic formations present in WV. The updated model code incorporates algorithms from both MINTEQA2 and MINEQL geochemical speciation models. MDAS upgrades with these capabilities are described in Tetra Tech's 2012 Technical Memorandum "Updated MDAS Model Capabilities Within the LSPC Modeling Framework" (Tetra Tech 2012).

The foundation of MINTEQA2/MINEQL is an equilibrium calculation for the major reactions that define the chemical composition of the stream reach during a given time-step. Most speciation reactions are fast relative to the time step, and the equilibrium assumption is reasonable. However, for certain reactions, such as the oxidation of ferrous iron to ferric iron or the adsorption of metals on iron oxyhydroxides, reactions may be limited by the kinetics, and may not necessarily reach equilibrium within one time-step. The major limitation of the equilibrium approach is mitigated by incorporating simultaneous equilibrium and kinetic (non-equilibrium) calculations within the same computational time step, leading to more precise spatial and temporal representations of non-equilibrium solution conditions for certain processes. The precipitation/dissolution and the adsorption/desorption reactions both occur in the water column and streambed sediments. The heat loading into the stream from land and point sources is also considered, and the resulting stream temperatures will be simulated first before starting pollutant modeling, since the stream temperature is used for all temperature-dependent chemical reactions occurring within the stream.

The hydrology component of MDAS uses Hydrologic Simulation Program-FORTRAN (HSPF) algorithms for simulating watershed hydrology, erosion, and water quality processes, as well as in-stream transport processes. HSPF is a comprehensive watershed and receiving water quality modeling framework that was originally developed in the mid-1970s. During the past several years it has been used to develop hundreds of USEPA-approved TMDLs, and it is generally considered the most advanced hydrologic and watershed loading model publicly available. The hydrologic portions of HSPF and LSPC are based on the Stanford Watershed Model (Crawford and Linsley 1966), which was one of the pioneering watershed models. The HSPF framework is developed in a modular fashion with many different components that can be assembled in different ways, depending on the objectives of the individual project.

The modules, discussed in more detail in Section 3.1.2.1, include many submodules that calculate the various hydrologic, sediment, and water quality processes in the watershed. Many options are available for both simplified and complex process formulations. Spatially, the watershed is divided into a series of subbasins or subwatersheds representing the drainage areas that contribute to each of the stream reaches. These subwatersheds are then further subdivided into segments representing different land uses. For the developed areas, the land use segments are further divided into pervious and impervious fractions. The stream network links the surface runoff and subsurface flow contributions from each of the land segments and subwatersheds, and routes them through the waterbodies using storage-routing techniques. The stream-routing component considers direct precipitation and evaporation from the water surfaces, as well as flow contributions from the watershed, tributaries, and upstream stream reaches. Flow withdrawals and diversions can also be accommodated.

The stream network is constructed to represent all the major tributary streams, as well as different portions of stream reaches where significant changes in water quality occur. Like the watershed components, several options are available for simulating water quality in the receiving waters. The simpler options consider transport through the waterways and represent all transformations and removal processes using simple, first-order decay approaches. Decay may be used to represent the net loss due to processes like settling and adsorption.

Summary of Recommended Framework

The selected framework for this TMDL effort is a comprehensive watershed modeling system representative of the processes essential for accurately modeling hydrology, flow routing, hydro-geochemical reactions, and water and bed sediment quality. Use of the existing MDAS framework will involve the configuration, calibration, and corroboration of the established modeling system utilizing existing data and information and building from and incorporating lessons learned in the earlier ion toxicity pilot modeling studies to address the TMDL modeling objectives and TMDL development. Application of the existing MDAS framework has the advantage of being consistent with that of the WVDEP TMDL development work for other impairments in the Lower Guyandotte River watershed which is being conducted concurrently.

2.4 Quality Objectives and Criteria for Model Inputs/Outputs

A key component of the modeling process is identifying and documenting the decision context for the project, addressed as general goals and objectives in Section 2.1. Model-specific objectives are described for MDAS (Section 3.1.1). Methods for evaluation of model performance are described further in Section 3.1.4.3.

3.0 MODEL DEVELOPMENT

The general project goals and objectives presented in Section 2 are translated into specific model development activities related to characterizing watershed pollutant loading in the Lower Guyandotte River watershed.

Environmental simulation models are simplified mathematical representations of complex real-world systems. Models cannot perfectly depict the multitude of processes occurring at all physical and temporal scales. Models can, however, make use of known interrelationships among variables to predict how a given quantity or variable would change in response to a change in an interdependent variable or forcing function. In this way, models can be useful frameworks for investigating how a system would likely respond to a perturbation from its current state. To provide a credible basis for predicting and evaluating mitigation options, the ability of the model to represent real-world conditions should be demonstrated through a process of model calibration and corroboration/validation (USEPA, 2009).

Model calibration and validation is conducted to ensure that the model is adequate to provide reasonable and appropriate information to answer the study questions. The objectives of model development are to adequately simulate existing pollutant sources and water quality conditions and develop allocation scenarios that result in attainment of the selected endpoint(s) for the stream segments biologically impaired by ionic toxicity. To address these objectives, the models must be able to provide credible representations of (1) water movement, (2) sediment movement, and (3) pollutant load generation and transport, (4) geochemical reactions of major ions. In addition, the model should facilitate comparisons to endpoints and evaluation of management actions.

The next subsections address each of the components of the MDAS modeling system.

3.1 Watershed Model – MDAS

3.1.1 Objectives

The modeling effort requires a source-response linkage and the estimation of existing loadings and target loadings to attain goals, as well as the distribution of those loads among sources and pathways to inform source reductions. The watershed model will provide a dynamic representation of flow and pollutant loads entering the streams represented by a series of connected stream reaches.

To meet the objectives discussed in Section 2.3, the watershed model will need to address pollutant loading from various sources and pathways including active mining areas, historical mining sites, industrial and other point sources, agricultural runoff, stormwater point and nonpoint sources, natural sources (e.g., forests), atmospheric deposition, and others.

As described in Section 2.3, the MDAS model is the selected framework for the watershed simulations. The MDAS watershed model developed under a separate contract with WVDEP for other impairments in the watershed can be used as a basis to create a watershed model framework for the ion toxicity TMDL development effort.

3.1.2 Model Representation of Sources and Processes

A key function of the watershed model is to develop an estimate consistent with available monitoring data of sources of pollutant loads and their link to receiving streams loads. Watershed-based sources and pathways may include:

- Discharges from active (permitted) mining areas
- Continuous discharges and runoff from legacy mining areas
- Urban runoff and associated loads
- Agricultural runoff and associated loads
- Runoff and other contributions from oil and gas drilling operations
- Other runoff such as from natural areas and associated loads,
- Atmospheric deposition, including spatial variation in deposition rates,
- Non-mining point source discharges (sewage treatment facilities, industrial, regulated stormwater outfalls, etc.), Spills and/or leaks (contaminated sites and industrial operations areas contributing high pollutant loads)

Pollutant loads are delivered to tributaries via surface runoff, subsurface flows, groundwater flows, direct point source discharges, and other pathways. Three potential chemical loading sources can be simulated at the modeled land surface in MDAS: atmospheric deposition, anthropogenic input, and existing chemical species (background) on the land associated with either natural or anthropogenic origins. While the wet/dry atmospheric deposition onto the stream reach can be explicitly modeled as direct deposits, the wet deposition on the land is assumed to be included implicitly in the loads generated at the surface.

The wet loads at the land surface are a mixture of the existing shallow depth pore solution and the wet deposition. The characterization of the mixed chemistry during the wet event can be modeled using MINTEQA2, MINEQL and/or PHREEQC by considering minerals at the shallow surface depth and weekly/monthly wet atmospheric deposition data from the national atmospheric deposition program. The values can also be based on observed values or some literature values. Through the user-assigned constant or the time variable mixed solution, the modeling is intended to simulate the dissolved portion of the surface chemical solution.

Both anthropogenic and naturally existing chemicals can be observed at the land surface. The mass of these chemicals can be time-variant depending on the source of the chemicals, the chemical evolution paths, source minerals, and past runoff patterns. The time variable build-up/wash-off functionality of the model can be applied to simulate the chemical condition of these sources. This approach is intended to represent the chemical constituents accumulated in a non-linear manner throughout the dry period. Subsequently, the land surface mass would be subjected to partial wash-off during the wet event. The method could be appropriate to simulate the chemical evolution of mine waste surfaces (e.g., simplified treatments of pyrite oxidation, salt accumulation on waste surfaces) and as a simulation of dry atmospheric deposition on the land. If the build-up/wash-off function is not appropriate for the chemicals or the land use being evaluated, sediment-attached chemicals can be simulated through adsorption onto clay and/or metal oxides through the edge-of-stream calculation. The wash-off could also be simulated using a potency factor to estimate the chemical mass associated with the sediment detached from the surface by the runoff.

As percolation/evapotranspiration occurs during and after the rainfall event, the moisture conditions of the subsurface zone are constantly updated. Due to the transient nature of the subsurface hydrology, the associated chemical loadings from these zones should also display time-variant characteristics. MDAS allows the user to input either constant or monthly chemical concentrations (including pH), or the charge/mass balance calculation method if the user-selected dataset indicates that all major cations and anions are accounted for and the solution attains electroneutrality. All of the chemical loadings from different flow domains (surface and subsurface) will contribute to the water quality conditions in the stream reach and be subjected to further chemical reactions within the reach.

The solution to the model equations for the reactions specified in MDAS is based on the MINTEQA2/MINEQL models with the thermodynamic database based on the MINTEQA2, Version 4.0 database. The concepts and thermodynamic data for the diffuse double layer (DDL) model for hydrous ferric oxide are based on a study conducted by Dzombak and Morel (1990). Research conducted by Tonkina, et al. (2003) and Karamalidis and Dzombak (2010) for adsorption on hydrous manganese oxide and gibbsite was reviewed and the results were incorporated into the MDAS DDL model data. Equilibrium constants for cation and anion adsorption and desorption on clays should be selected based on the site-specific data or the literature values. Table 2 shows all significant chemical species, other than the free ions, currently included in MDAS database for a chemical system based on major ions, aluminum, iron, and manganese, and adsorption/desorption to oxides and clays.

Table 2. Chemical components and complexes included in previous and updated versions of MDAS.

Components	Aqueous Species		Adsorbed Species		Solids
H^{+}	H^{+}	$Fe(OH)_2^{+}$	$:FehO^{-}$	KX	Iron
Ca^{+2}	Na^{+}	$Fe(OH)_3$ (aq)	$:FehOH_2^{+}$	CaX_2	Aluminum
CO_3^{-2}	K^{+}	$Fe(OH)_4^{-}$	$:FehOHCa^{+2}$	MgX_2	Manganese
Fe^{+3}	Ca^{+2}	$Fe_2(OH)_2^{+4}$	$:FehOHSO_4^{-2}$	AlX_3	Calcite
Fe^{+2}	Mg^{+2}	$Fe_3(OH)_4^{+5}$	$:FehSO_4^{-}$	FeX_2	Gypsum
Mn^{+2}	Al^{+3}	$FeSO_4^{+}$	$:FehOMn^{+}$	MnX_2	Jurbanite
Mn^{+3}	Fe^{+2}	$Fe(SO_4)_2^{-}$	$:FehO(FeII)^{+}$	-	-
Al^{+3}	Fe^{+3}	$FeCl^{+2}$	$:FehCO_3^{-}$	-	-
SO_4^{-2}	Mn^{+2}	KCl (aq)	$:FehCO_3H$	-	-
H_2O	Mn^{+3}	KOH (aq)	$:FeO^{-}$	-	-
Na^{+}	SO_4^{-2}	KSO_4^{-}	$:FeOH_2^{+}$	-	-
K^{+}	Cl^{-}	$MgCl^{+}$	$:FeOCa^{+}$	-	-
Mg^{+2}	CO_3^{-2}	$MgOH^{+}$	$:FeOMg^{+}$	-	-

Components	Aqueous Species		Adsorbed Species		Solids
Cl^-	$AlOH^{+2}$	$MgSO_4$ (aq)	$:FeOHSO_4^{-2}$	-	-
FeOH(s)	$Al(OH)_2^+$	$MgCO_3$ (aq)	$:FeSO_4^-$	-	-
FehOH (s)	$Al(OH)_3$ (aq)	$MgHCO_3^+$	$:FeOMn^+$	-	-
AlOH (s)	$Al(OH)_4^-$	$MnOH^+$	$:FeO(FeII)^+$	-	-
MnOH (s)	$Al_2(OH)_2^{+4}$	$Mn(OH)_4^{-2}$	:FeO(FeII)OH	-	-
MnhOH (s)	$Al_3(OH)_4^{+5}$	$Mn_2(OH)_3^+$	$:FeCO_3^-$	-	-
X^-	$Al_2(OH)_2CO_3^{+2}$	Mn_2OH^{+3}	$:FeCO_3H$	-	-
-	$AlCl^{+2}$	$MnSO_4$ (aq)	$:AlO^-$	-	-
-	$AlSO_4^+$	$MnCl^+$	$:AlOH_2^+$	-	-
-	$Al(SO_4)_2^-$	$MnCl_2$ (aq)	$:AlOCa^+$	-	-
-	$CaOH^+$	$MnCl_3^-$	$:AlOHSO_4^{-2}$	-	-
-	$CaSO_4$ (aq)	$MnCO_3$ (aq)	$:AlSO_4^-$	-	-
-	$CaCl^+$	$MnHCO_3^+$	$:AlOFe^+$	-	-
-	$CaCO_3$ (aq)	NaCl (aq)	$:AlOMn^+$	-	-
-	$CaHCO_3^+$	NaOH (aq)	$:MnO^-$	-	-
-	$FeOH^+$	$NaSO_4^-$	$:MnOCa^+$	-	-
-	$Fe(OH)_2$ (aq)	$NaCO_3^-$	$:MnOMg^+$	-	-
-	$Fe(OH)_3^-$	$NaHCO_3$ (aq)	:MnOMgOH	-	-
-	$FeSO_4$ (aq)	HSO_4^-	$:MnOMn^+$	-	-
-	$FeCl^+$	$H_2CO_3^*$ (aq)	:MnOMnOH	-	-
-	$FeHCO_3^+$	HCO_3^-	$:MnhO^-$	-	-
-	$FeOH^{+2}$	OH^-	NaX	-	-

Notes: 'h' indicates a high affinity site for chemical adsorption. Species with the same combination of components but no 'h' have a low affinity site. In reality, species with and without the 'h' are physically identical, but the designation is applied within the model to explain observed adsorption behavior.

'X' indicates a clay adsorption site.

':' indicates an adsorption surface provided by metals (Fe: hydrous ferric oxide, Al: gibbsite, Mn: hydrous manganese oxide).

3.1.2.1 Hydrology

MDAS provide a dynamic, continuous simulation of hydrology and water quality processes. The simulation occurs at a user-specified time step. For water quality applications, an hourly time step is typically appropriate. This is sufficient to capture the storm event hydrograph and to represent major washoff and erosion events.

Hydrology in MDAS is identical to HSPF/LSPC. Multiple hydrologic components are contained within MDAS including precipitation, interception, evapotranspiration (ET), overland flow, infiltration, interflow, subsurface storage, groundwater flow, and groundwater loss. The figure below provides a graphical representation of these processes (capitalized acronyms are computer code routine names). Rain falls and lands on constructed landscapes, vegetation, and soil. Varying soil types allow the water to infiltrate at different rates (using the Philip infiltration algorithm) or enter shallow interflow pathways, while evaporation and plant matter exert a demand on available water. Water flows overland and through the soil matrix. The land representation in the MDAS model contains three major flow pathways: surface, interflow, and groundwater outflow.

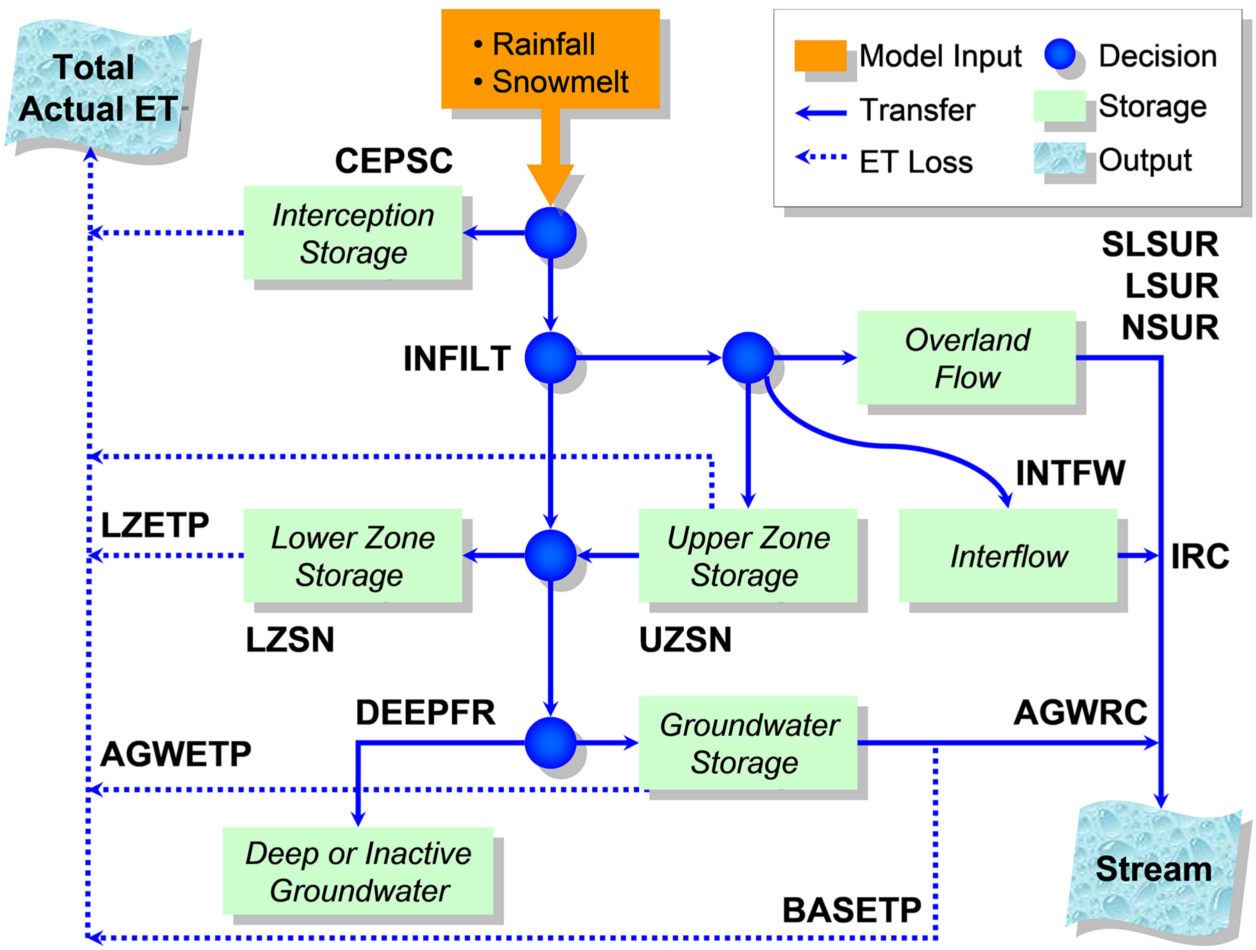

Figure 4. Hydrologic representation in the MDAS model

Note: Entries in **ALL CAPITALS** identify key model state variables that determine the magnitude of different pathways.

3.1.2.2 Ions and chemical loading

The chemical loadings from land are simulated through hydrologic surface and subsurface modeled domains assigned to each land use in the basin. Observed dissolved chemicals (cations and anions) and mineral concentrations with associated observed pH can be assigned to the hydrologic domains/land uses categories of the model initially and then modified during the calibration process. Input chemical concentrations can be constant throughout the simulation period or monthly variables depending on the available data type and the project objectives. The model also provides two additional functionalities to simulate land surface chemical loadings: 1) chemical build-up/wash-off and 2) sediment-associated chemicals using potency factors.

The modeled chemical/mineral loadings from the land surface will enter edge-of-stream calculations to undergo the thermodynamic equilibrium distribution of the assigned chemical components into dissolved chemicals and sediment-associated chemicals. The edge-of-stream calculations use the same computational method employed in MINTEQA2 and MINEQL. The model also provides the option to determine pH, track speciation and adsorption/desorption of the simulated chemicals and generate land loadings through an additional chemical charge/mass balance method.

3.1.2.3 Ions and chemical fate and transport

The stream components in MDAS include the dominant processes regulating the interactions and transport of major ions, metals, adsorbing materials, and mineral phases. Reactions between the water column and the streambed are represented along with the reactions governing the distribution of dissolved and particulate chemicals.

The streambed consists of two virtual model layers. The first layer in the model is represented as an active sediment layer that participates in all chemical reactions. The second modeled layer is represented as a non-active sediment layer but contributes to total sediment and mineral mass. The active layer is thought to be either freshly precipitated minerals or shallow sediment layer that reacts with chemicals/minerals in the overlaying water within the modeled computational time step. The non-active layer is assumed to be aged and has lost chemical reactivity. Both layers are subjected to sediment aging and/or burial. The model sediments are represented by sand (as non-cohesive sediment), and silt and clay (as cohesive sediment). The cohesive sediment of the clay can be further divided into metal oxides and minerals. Minerals include solid phases, such as calcite, gypsum, jurbanite, and others, that could potentially be present in acidic/post-remedial-solution discharges from mine sources or other wastes.

Deposition to and scour from the streambed sediments are simulated on both the active and the non-active layer in the stream channel, with full simulated transport with adsorbed chemicals. The exchange between the water column and the streambed of clay, metal oxides, and other minerals is dependent on the shear stress at the benthic layer and is calculated from the reach slope and hydraulic radius.

All or some of these dissolved, particulate, and adsorbed chemicals will be transported to downstream reaches depending on the flow conditions. The transported chemicals will be subject to additional reactions and transport in downstream reaches.

While the equilibrium approach is suitable for many of the reactions in the model, additional non-equilibrium processes and reactions are represented by kinetic formulations in order to provide a greater accuracy in the stream environment. Kinetics are applied to the following:

- Degassing/ingassing of CO_2
- Lake reaeration
- Calcite dissolution and precipitation
- Metal oxides, gypsum and jurbanite dissolution and precipitation
- Metals oxidation/reduction
- Aging/burial of active sediment layer

Additional model capabilities include the previously mentioned atmospheric deposition input to the model and point source loadings addition to and subtraction from the modeled reach. The MDAS model derives total hydrogen (TH) with the edge-of-stream calculations to generate more precise TH calculations and accurately represent the chemical mass balance within a stream. Point source loadings can also be added or abstracted through MDAS model configuration. Conductivity can be calculated by developing either a linear or power relationship between all dissolved chemical concentrations and the conductivity values. The coefficients and the equation should be derived from observed data to accurately model the conductivity.

3.1.3 Model Configuration

The MDAS model configured for TMDL development for other impairments in the Lower Guyandotte River watershed includes delineation of 544 subwatersheds. This existing fine scale delineation can be used as a starting point for the ionic toxicity TMDL modeling. The final list of biologically impaired segments with ionic toxicity shown in Table 1 will determine the subwatersheds addressed in this effort.

3.1.4 Model Calibration and Evaluation

3.1.4.1 Objectives

Model calibration consists of the process of adjusting model state variables to reasonably represent the observed conditions. Calibration is necessary because of the semi-empirical nature of watershed models. Although these models are formulated from mass balance principles, most of the kinetic descriptions in the models are empirically derived. These empirical derivations contain a number of coefficients that are usually determined by calibration to data collected in the waterbody of interest.

3.1.4.2 Approach and Time Period

The watershed model will be calibrated and validated through a sequential process, beginning with hydrology and then water quality.

3.1.4.2.1 Time Period

Calibration of watershed models benefits from a relatively long time period that covers a range of climatic conditions and allows full stabilization of water storage. The TMDL model will set the simulation period to cover the pre-TMDL monitoring period. A spin-up period (two or three months up to a few years) is required to stabilize the various model simulated storages (i.e. upper zone storage, lower zone storage, etc.), which begin the simulation as user defined initial conditions. In practice, this means that the actual calibration period of the model begins a few months to a year into the simulation.

3.1.4.2.2 *Hydrologic Calibration*

Hydrologic calibration will use standard operating procedures. Those are described for the HSPF (and LSPC) model in BASINS Technical Note 6 on *Estimating Hydrology and Hydraulic Parameters for HSPF* (USEPA, 2000). MDAS model has the same hydrology module as LSPC. The hydrologic calibration follows the same rules as HSPF/LSPC model.

Model output will be compared to, among other things, the annual water balance, low/high flow distribution, storm peaks, hydrograph shape, seasonal variation, and other statistical measures that capture performance at the model time step (e.g. root mean square). The Lower Guyandotte River watershed model has already been calibrated for hydrology, so it is expected that any required adjustments that result from the ionic toxicity TMDL model extension will be minimal Tetra Tech is currently under contract to WVDEP to comprehensively model fecal coliform and total iron in the Lower Guyandotte River watershed. Water quality calibration deliverables under that contract are due September 2020. Those calibrations will not significantly impact the ionic toxicity work, which will require pH modeling/calibration that will not be generally available from the base Lower Guyandotte project to simulate/calibrate important ion concentrations. In general, when calibrating HRU (land segment) hydrology, parameters are adjusted iteratively to achieve agreement between simulated and observed stream flows at specified locations throughout the basin. Agreement between observed and simulated stream flow data are evaluated on annual and seasonal bases using quantitative and qualitative measures. Specifically, annual water balance, groundwater volumes and recession rates, and surface runoff and interflow volumes and timing are evaluated, along with composite comparisons (e.g., average monthly stream flow values over the period of record). In sum, the level of performance and overall quality of hydrologic calibration will be evaluated in a weight of evidence approach that includes both visual comparisons and quantitative statistical measures. The calibration will proceed in a sequential manner through (1) general representation of the overall water balance, (2) assurance of consistency with satellite-based estimates of actual ET and soil moisture, and (3) detailed calibration relative to flow gaging for seasonal flows, shape of the flow duration curve, and hydrograph shape.

Key parameters for hydrologic calibration and information on their potential ranges are as described in USEPA (2000). When developing initial values, key parameters can be related to soil and climatological properties where appropriate. Specifically, infiltration rates (INFILT) can be initialized by (and subsequently varied by) the NRCS hydrologic soil group (HSG), while initial values of lower zone nominal soil storage capacity (LZSN), upper zone soil storage capacity (UZSN), and interflow inflow (INTFW) can be set based on annual average rainfall, consistent with recommendations in USEPA (2000).

Typically, hydrology calibration involves a comparison of model results to in-stream flow observations from USGS flow gaging stations throughout the watershed. However, there are no USGS flow gaging stations with adequate data records for model hydrology calibration on streams in the Lower Guyandotte River watershed modeled for this effort. Instead, a reference approach will be used to define initial hydrologic parameters used in the model. Model hydrology parameters developed for the recently completed LSPC (MDAS) model for the upstream and hydrologically similar Upper Guyandotte River watershed will be applied to the Lower Guyandotte model. Three USGS flow gages were used to calibrate model hydrology in the Upper Guyandotte TMDL development effort.

Although there are no usable USGS gages in the Lower Guyandotte River watershed, some additional flow data are available in WVDEP water quality monitoring data. WVDEP flow data are limited to one observation per month (collected when stream conditions were safe for wading). No high flows were observed. Lower Guyandotte model hydrology will be validated by comparing model output to in-stream flow measurements obtained at pre-TMDL monitoring stations during WVDEP's 2017-2018 pre-TMDL water quality monitoring. Final adjustments to model hydrology will be made, if necessary, based on this validation.

WVDEP has deployed level loggers at three selected locations to help inform hydrology calibration of valley fills. The data generated from that effort and the USGS publication *Relations Between Precipitation and Daily and Monthly Mean Flows in Gaged, Unmined and Valley-Filled Watersheds, Ballard Fork, West Virginia, 1999–2001* (Messinger and Paybins, 2003) will be considered.

3.1.4.2.3 Water Quality Calibration

The discussion of key data sources relevant to model calibration is provided in Section 4.1.1. State variables for background conditions will be based on observed water quality data from undisturbed monitored locations. Starting values for other nonmonitored sources will be taken from previous models, literature, and peer-recommended ranges. The approach taken to calibrate water quality will focus on evaluating the trends of the ions that are identified during the endpoint analysis. Upon completion of the calibration at selected locations, the calibrated dataset containing state variable values for modeled sources and pollutants will be complete. This dataset will be applied to areas for which calibration data are not available. The time-period for water quality calibration should be selected based on the availability of the observed data and their relevance to the current conditions in the watershed. Water quality data from WVDEP's pre-TMDL monitoring efforts in 2017-2018 will serve as the primary calibration dataset and will be supplemented with the continuous monitoring data collected by WVDEP during 2020.

3.1.4.3 Evaluation Criteria

The MDAS model will be sequentially calibrated for flow and ions/dissolved solids fate and transport. The evaluation approaches for flow/hydrology and water quality are provided below.

3.1.4.3.1 *Hydrology*

The level of performance and overall quality of hydrologic calibration is evaluated in a weight of evidence approach that includes both visual comparisons and quantitative statistical measures. Given the inherent errors in input and observed data and the approximate nature of model formulations, absolute criteria for watershed model acceptance or rejection are not generally considered appropriate by most modeling professionals. In most cases, model acceptance is based on several factors and constraints confronting modelers and decision makers. These include but are not limited to inherent modeling uncertainty, site-specific system complexity, data limitations, impact of model-based decisions, project budget, project schedule, peer review findings, and the likelihood of model improvement with additional calibration effort. For this reason, basic evaluation approaches are described below, and it is anticipated that an iterative process will be incorporated for acceptability of performance in the course of routine project communications. Technical difficulties or limitations will be discussed in general communications and, if necessary, based on specific observations or evaluation results, a broader work group may need to be convened to develop consensus on acceptability of performance or on an alternate approach to minimize the effect of the apparent limitations.

Typically recommended criteria are based on statistical error over a range of flow conditions, which requires continuous flow records, usually from USGS flow gages. There are no continuous flow gages in the Lower Guyandotte watershed; however, there are continuous flow gages in the Upper Guyandotte watershed, and these are being used for hydrology calibration in the current watershed modeling that Tetra Tech is conducting for WVDEP. Hydrology parameters from that modeling effort will be used in the current effort, and visual inspection will be used to verify the results by comparing them to the limited instantaneous flow measurements at water quality sampling locations.

3.1.4.3.2 *Water Quality*

Water quality observations typically provide measurements of conditions at a point in time and point in space via a grab sample. The discrete nature of these samples presents problems for model calibration: A sample that represents a point in time could have been obtained from a system where conditions are changing rapidly over time – for instance, the rising limb of a storm hydrograph. Such samples cannot be expected to be reproduced by a model prediction of a daily average concentration. On the other hand, there may be large discrepancies between dynamic model predictions of hourly concentrations and data that are a result of small timing errors in the prediction of storm event flow peaks. Spatially, grab samples reflect conditions in one part of a stream reach (which may or may not be composited over the width and depth of a cross section). MDAS model results, in contrast, represent average concentrations over the length of a stream reach which is assumed to be fully mixed. Model predictions and field observations inevitably have some degree of mismatch in space and time and, even in the best models, will not fully match. The grab samples will also be supplemented by continuous conductivity monitors at key instream locations and at known significant ion sources that WVDEP plans to monitor during 2020. This data will be especially useful in model calibration to capture the changing conditions over time. Accordingly, the calibration and validation will be evaluated using a combination of visual inspection and a statistical best fit approach as needed.

3.2 Model Application and TMDL Development

Once the model is calibrated and validated the project team will have a better understanding of its limitations based on performance testing. To determine if the model is acceptable, spatial trends, temporal trends, orders of magnitude for both high and low concentrations will be reviewed. While both high and low concentrations should be captured, it is anticipated that high concentrations will occur during both high and low flow conditions, depending on the ion and the specific sources that are contributing ion concentrations. It is important to capture both the high and low flow critical conditions because the TMDL endpoint development is occurring in parallel to the model development and will determine the most appropriate chronic concentration of specific ions and/or conductivity.

While acceptance criteria for water quality calibration would preferably be based on statistics, directly evaluating continuous hourly model output based on statistical relationships to instantaneous monthly grab samples would not be appropriate for the reasons described in Section 3.1.4.3.2. Given the need to capture both high and low flow critical conditions and the limited data, visual inspection of model performance against temporal trends in instantaneous water quality observations will be used. Calibration results will be deemed acceptable when model results fall within an order of magnitude of water quality observations except when outliers are identified.

WVDEP is currently collecting data from a number of continuous conductivity meters at strategic locations throughout the Lower Guyandotte watershed. Depending on the quality of these data, statistical best fit approaches may be applied to further justify calibration.

After accepted for use, the model will be used to assess pollutant sources, loadings, fate/transport, and develop allocation scenarios to achieve the selected endpoint(s). This assessment will require the development of load reduction scenarios that result in achievement of the applicable endpoint(s). The type of load reductions required to achieve the endpoint(s) cannot be determined prior to the commencement of model development.

Tetra Tech envisions working closely with EPA and WVDEP to explore various allocation scenarios (minimum 2 TMDL allocation scenarios) and the potential pathways of allocation strategies to reach the endpoint target. Initially a "top-down" approach could be pursued where substantive sources in headwaters are reduced to the extent necessary to attain endpoints at subwatershed pourpoints. Residual loadings would then be transferred to downstream subwatersheds where the allocation methodology would be repeated. Alternatively, the allocation approach can start with a universal reduction of ion concentrations on major sources and then use the watershed approach to reduce ion concentrations of remaining nonattaining segments on a case-by-case basis. Allocations will include an explicit margin of safety (MOS), if directed. Allocations will target load reductions for the most significant sources whereby allocations to precipitation-induced sources will not be more stringent than concentrations of equivalent pollutants resulting from background conditions, and allocations to point sources will not be more stringent than numerical endpoints. Seasonality will be considered in allocations if relevant to ionic toxicity resolution. Future growth conditions for ionic sources will be considered and allocations provided, if directed.

3.3 Model Documentation (A9)

Model documentation will be a critical aspect of the project. The objective of model documentation will be to record all actions and assumptions made in developing the models. To meet this objective, a logbook will be kept to document data sources, assumptions, methodology and decisions. As each phase of the model development (e.g., calibration) is completed, a draft chapter documenting the work will be prepared and reviewed. At project team meetings, decisions needed for the project will be reviewed and documented. Version control will be achieved by housing all modeling and report files on a central server in an organized file structure. Important modeling and report files will be named with a "year-month-day" suffix to track iterations through the TMDL development process. The Tetra Tech Quality Control Officer will be ultimately responsible for curating all project files and maintaining version control.

A final report documenting all aspects of the model development, calibration, and assessment will be prepared for this project once the model is accepted. Model TMDL calculation and load allocations will be documented as well, likely as a chapter incorporated into the model development report.

In addition to model development documentation, a model selection report was developed to document the modeling requirements, previous work and available modeling tools, and an evaluation and summary of MDAS capabilities. The Technical Support for West Virginia Ionic Toxicity TMDLs Model Selection report was delivered to EPA in January 2020.

4.0 DATA SOURCES (B9)

The model will be developed with the existing body of data for the Lower Guyandotte River watershed. The ramifications of possible data gaps on model confidence/uncertainty will not be fully understood until the model calibration process is underway. It is anticipated that the data gaps in sampling of surface water quality will present the largest challenge, particularly for the tributaries of the Lower Guyandotte River.

The model development process will be conducted in phases, beginning with hydrology and hydrodynamic modules of MDAS. Once the flow model is complete and water quality data are assembled in a database, the project plan includes parallel tasks to develop empirical loading estimates and to calibrate the water quality models. Any significant adjustments to the model development process would be captured in updates or addenda to this QAPP.

4.1 Data Summary

Secondary data are data previously collected by others under an effort outside of the current project that are used for model development and calibration. Table 3 lists the secondary sources that will serve as the platform for TMDL model development. The sections that follow provide additional details regarding secondary data used for this task.

Table 3. Sources of key secondary data

Type of Information	Data Sources
Watershed physiographic data	
Stream network	USGS National Hydrography Dataset (NHD)
Landuse	National Land Cover Dataset 2016 (NLCD)
2016 Aerial Photography (1-meter resolution)	National Agriculture Imagery Program (NAIP)
Counties	U.S. Census Bureau
Cities/populated places	U.S. Census Bureau
Soils	State Soil Geographic Database (STATSGO) U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) soil surveys
Hydrologic Unit Code boundaries	U.S. Geological Survey (USGS)
Topographic and digital elevation models (DEMs)	National Elevation Dataset (NED)
Dam locations	USGS
Roads	U.S. Census Bureau TIGER, WVU WV Roads
Water quality monitoring station locations	WVDEP, USEPA STORET
Meteorological station locations	National Oceanic and Atmospheric Administration, National Climatic Data Center (NOAA-NCDC)
Permitted facility information	WVDEP Division of Water and Waste Management (DWWM), WVDEP Division of Mining and Reclamation (DMR)

Type of Information	Data Sources
Timber harvest data	WV Division of Forestry
Oil and gas operations coverage	WVDEP Office of Oil and Gas (OOG)
Abandoned mining coverage	WVDEP DMR
Monitoring data	
Historical Flow Record (daily averages)	USGS
Rainfall	NOAA-NCDC, PRISM, NLDAS
Air Temperature	NOAA-NCDC, PRISM, NLDAS
Wind speed	NOAA-NCDC, NLDAS
Dew point	NOAA-NCDC, NLDAS
Humidity	NOAA-NCDC, NLDAS
Cloud cover	NOAA-NCDC
Water quality monitoring data	USEPA STORET, WVDEP
National Pollutant Discharge Elimination System (NPDES) data	WVDEP DMR, WVDEP DWWM
Discharge Monitoring Report data	WVDEP DMR, Mining Companies
Abandoned mine land data	WVDEP DMR, WVDEP DWWM
Regulatory or policy information	
Applicable water quality standards	WVDEP
Section 303(d) list of impaired waterbodies	WVDEP, USEPA
Nonpoint Source Management Plans	WVDEP

The sections below describe the data summary for the MDAS model to be developed.

Flow Data

Reliable streamflow data are important to watershed model development and calibration and validation. Flow data are not available for the Lower Guyandotte watershed, and the hydrology will be calibrated using a reference watershed approach using the flow data available in the Upper Guyandotte watershed. Flow data at locations within the model domain of the Upper Guyandotte will be compared against modeled flow to evaluate the model performance and the resulting calibrated hydrology parameters will be transferred to the Lower Guyandotte watershed.

Meteorological Forcing Data

Meteorological data were obtained from a number of weather stations in an effort to develop the most representative dataset for each watershed.

Appropriate spatial resolution of weather data is also important when modeling the hydrology of mountainous watersheds in West Virginia where abrupt changes in topography are common between mountains and valleys. Two grid-based data products were used to develop model weather input files with appropriate spatial and temporal resolution. The Parameter-Elevation Regressions on Independent Slopes Model (PRISM) and the North American Land Data Assimilation System (NLDAS-2) are both publicly available weather datasets. They can be used separately or together to generate comprehensive weather input files at a fine spatial resolution.

The PRISM dataset was developed by Oregon State University's PRISM Climate Group. The PRISM dataset provides daily, monthly, yearly, and single-event gridded data products of mean temperature and precipitation, and max/min temperatures. PRISM uses a combination of climatologically-aided interpolation (CAI) and Radar (National Weather Service Stage 2 unbiased). The dataset uses a robust network of weather station point measurements incorporated into the PRISM statistical mapping system (PRISM Climate Group, 2014). PRISM products use a weighted regression scheme to account for complex climate regimes associated with orography, rain shadows, temperature inversions, slope aspect, coastal proximity, and other factors. PRISM data features daily weather on 4 kilometer (km) grid spatial scale.

The NLDAS-2 dataset is maintained through a partnership between the National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), and several large universities (Cosgrove et al., 2003). It combines rain gage data with Radar observations to predict hourly weather parameters such as precipitation, solar radiation, wind, and humidity. NLDAS-2 data has hourly weather on a 12 km grid scale.

NLDAS-2 and PRISM datasets are broadly used by various user communities in modeling, research, and applications (NCAR, 2013). PRISM was chosen for TMDL modeling purposes because it featured a higher spatial resolution than NLDAS-2. However, hourly precipitation from the NLDAS-2 dataset was also extracted and used along with supporting data from NOAA National Climatic Data Center (NCDC) Surface Airways Stations to manipulate the daily PRISM weather data into hourly model input files.

PRISM daily time series data was downloaded at 2.5 arc minutes (~4 km) resolution from the PRISM website. Precipitation and max/min temperature data for each grid cell that intersected with TMDL watersheds were identified and processed to create a time series for each 4 km x 4 km grid cell. Once the precipitation and temperature time series for the PRISM grid cell files were created, a weather input file was developed for each grid cell. Given that slight variability was observed between the grid cells at the 12-digit Hydrologic Unit Code (HUC) scale and to allow more feasibility when executing the models, one centrally located weather input file per HUC was identified as representative of the weather in the area. Model subwatersheds falling within each 12-digit HUC were then assigned the appropriate weather input file for hydrologic modeling purposes.

Water Quality Observations

Water quality data across the Lower Guyandotte River watershed from 1970-2019 was provided by WVDEP. The more recent (pre-TMDL monitoring; 2017/2018 and later) monitoring of ionic constituents will be used to develop and calibrate the ionic toxicity model.

During the pre-TMDL monitoring period, quarterly monitoring of important ion constituents occurred at many Lower Guyandotte River tributaries and will be available for model calibration. Data gaps may be determined after consideration of the final list of biologically impaired segments with ionic toxicity. WVDEP has advised that more recent monitoring has been conducted to address potential gaps in stream monitoring and to characterize potential sources; however, a lesser amount of data may be available for those locations.

WVDEP is also planning deployment of continuous conductivity monitors at key instream locations in streams with known biological impairment from ionic toxicity and at known significant ion sources. This data will be especially useful to source representation and model calibration activities.

Another potentially valuable data source is the Discharge Monitoring Report data resulting from the self-monitoring required of NPDES permittees. Ionic constituent data may be available at both outlet and instream locations. The Discharge Monitoring Report format (average monthly/maximum daily result reporting) may limit the utility of this data for direct use in calibration, but it may be able to be used qualitatively to potentially refine source representation to improve calibration. Discrete sample results are not readily available because the permit terms and conditions require only summary information to be routinely reported. WVDEP or EPA can use authority under CWA Section 308 to make a formal request to obtain discrete sample data. WVDEP has pursued this in the past with very limited success. Tetra Tech will consider such information if obtained and as qualified by EPA and WVDEP relative to QA/QC considerations.

Reach Hydraulics and Subwatersheds

In the MDAS model, each subwatershed has a representative reach, which was identified using the USGS NHD stream coverage.

To route flow and pollutants, rating curves were developed for each stream using Manning's equation and representative stream data. Required stream data include slope, Manning's roughness coefficient, and stream dimensions, including mean depths and channel widths. Manning's roughness coefficient was assumed to be 0.03 (representative of natural streams) for all streams. Slopes were calculated based on DEM data and stream lengths measured from the NHD stream coverage. Stream dimensions were estimated using regression curves that related upstream drainage area to stream dimensions (Rosgen, 1996).

Source Representation

The model will be configured for the ion sources that are present in the watershed with a focus on sources found to be most influencing. The landuse coverage developed for Tetra Tech's existing C4 Lower Guyandotte TMDL project will be used as a starting point for this project and modified as necessary to address concerns of this project. Sources can be classified as point (permitted) or nonpoint (non-permitted) sources. Point sources will be classified by the mining and non-mining-related permits issued by WVDEP. Non-permitted (nonpoint) sources may also contribute ions. For example, disturbed lands and continuous flow seeps from abandoned mine lands and septic systems and straight pipes may be present and significant contributors of ions, and stormwater runoff from roads and developed areas may contribute elevated ions associated with deicing operations. Additional consideration will be afforded to the mechanisms by which certain subclasses provide ionic loading to streams (i.e. continuous flow discharges vs. precipitation–induced runoff from land features). Loading of continuous discharges will be based upon flow and concentration input data, and precipitation-induced sources will be configured based upon area, precipitation and landuse-based coefficients for modeled variables, including key ions and all other related state variables. Although the model will provide detailed landuse classification to the extent practical, modeled landuses that are not deemed significant with respect to ionic loading may be classified as background loading.

The existing modeling effort for the C4 Lower Guyandotte TMDL project will form the basis for characterizing the loading function mechanisms of watershed sources of ions. Existing information for ionic characterization will be compiled for monitored sources (ex. permit discharge monitoring reports). The model representation of the unique hydrological processes of valley fills can also be explored with a combination of rainfall-runoff process on land surface and soil matrix reservoir configuration. The objective will be to best simulate the concentration and loading of variable of interest at low flow, mean flow, and storm peaks at representative water quality monitoring stations.

Land Cover/Land Use and Soils

The existing NLCD 2016 landuse categories were consolidated to create the modeled landuse using the method described for ion toxicity. Additional landuse categories were created from various sources to produce a more detailed landuse set that represented specific land-based sources of ions and chemical loading. Table 4 displays the additional landuse categories and the datasets from which they were created.

Table 4. Additional modeled landuse categories

Model Category	Source
Burned Forest	Burned area details provided by Division of Forestry
Harvested Forest	Logging sites and areas provided by Division of Forestry
Skid Roads	Skid road areas provided by Division of Forestry
Roads_Paved	2011 TIGER/Line GIS and WV_Roads shapefiles
Roads_Unpaved	2011 TIGER/Line GIS shapefile and digitized from aerial photographs and topos
Oil and Gas	OOG shapefile provided by Office of Oil and Gas
Marcellus Shale Wells	Permit information provided by Office of Oil and Gas
Surface Mining	HPU shapefile and information gathered from SMCRA Article 3 permits by WVDEP personnel
Revoked	Bond Forfeiture information provided by WVDEP
Highwall	AML highwall shapefile provided by WVDEP
Construction Stormwater	Construction Stormwater permits provided by WVDEP
Industrial Stormwater	Industrial Stormwater permits provided by WVDEP
Future Growth	A certain percentage of each subwatershed’s area was set aside for future growth

Atmospheric Deposition

Acid rain is produced when atmospheric moisture reacts with gases to form sulfuric acid, nitric acid, and carbonic acid. These gases are primarily formed from nitrogen dioxides and sulfur dioxide, which enter the atmosphere through exhaust and smoke from burning fossil fuels such as gas, oil, and coal. Two-thirds of sulfur dioxides and one-fourth of nitrogen oxides present in the atmosphere are attributed to fossil fuel burning electric power generating plants (USEPA, 2005). Acid rain crosses watershed boundaries and may originate in the Ohio River Valley or the Midwestern United States.

The majority of the acid deposition occurs in the eastern United States. In March 2005, the USEPA issued the Clean Air Interstate Rule (CAIR), which places caps on emissions for sulfur dioxide and nitrogen dioxides for the eastern United States. It was expected that CAIR would reduce sulfur dioxide emissions by over 70 percent and nitrogen oxides emissions by over 60 percent from the 2003 emission levels (USEPA, 2005).

Effective January 1, 2015, CAIR was replaced by the Cross-State Air Pollution Rule (CSAPR). Similar to CAIR, CSAPR also places caps on emissions for sulfur dioxide and nitrogen oxides for the eastern United States. Combined with other final state and EPA actions, CSAPR will reduce power plant SO_2 emissions by 73 percent and NO_X emissions by 54 percent from 2005 levels in the CSAPR region (USEPA, 2016b). Because pollution is highly mobile in the atmosphere, reductions based on CSAPR in West Virginia, Ohio, and Pennsylvania will likely improve the quality of precipitation in the watershed. Effective September 7, 2016, USEPA issued the Final Cross-State Air Pollution Rule Update. This update finalized Federal Implementation Plans (FIPs) in the CSAPR Update to address air quality impacts of the interstate transport of ozone air pollution in the eastern United States (USEPA, 2016c).

Acid deposition occurs by two main methods: wet and dry. Wet deposition occurs through rain, fog, and snow. Dry deposition originates from gases and particles. Dry deposition accounts for approximately half of the atmospheric deposition of acidity (USEPA, 2005). Winds blow the particles and gases contributing to acid deposition over large distances, including state boundaries. After dry deposition occurs, particles and gases can be washed into streams from trees, roofs, and other surfaces by precipitation.

Weekly wet deposition data were retrieved from National Atmospheric Deposition Program station WV04-Babcock State Park in Fayette County from 2000 to 2014. The Clean Air Status and Trends Network (CASTNET) was accessed to retrieve dry deposition data from CDR119 in Gilmer County.

4.2 Model Data Gaps and Methods to Address Them

Initial state variable-specific data gaps were discussed in Section 1.3. Building on these, model-specific gaps are discussed below.

A review of the existing data suggested gaps for continuous flow monitoring data in the watershed. The continuous flow data would largely benefit hydrologic calibration and thus help water quality simulation too.

These will be input into the model at a minimum of monthly average or up to daily frequencies according to data availability. Inputs for point sources typically includes flow volume and either loads or concentrations. Not all point sources have been monitored for all constituents that are needed for model input. Filling of missing data is conducted in three general ways. First, if there are gaps in the data that are three months or less, an average will be calculated from before and after gap months. Second, if the gaps in the data are larger than three months the long-term monthly average will be supplied. Lastly, if no information for a particular constituent that is required for the model exists then a default assumption will be utilized. Default assumptions will be developed in consultation with project team members. Data for these types of point sources, from a modeling perspective, is not considered a significant gap at this time.

4.3 Quality Control for Secondary Data (A7, B9)

Most of the secondary measurements will be obtained from quality assured sources. Tetra Tech will assume that data, documents and databases obtained from federal and state sources have been screened and meet specified measurement performance criteria. Such criteria might not be reported for the state variables of interest in the documents or databases. During model development, Tetra Tech will identify any data anomalies that warrant analysis of quality assurance information for a particular dataset. Tetra Tech will perform general quality checks on the transfer of data from any source databases to another database, spreadsheet, or document.

Where data are obtained from other sources lacking an established data quality program, Tetra Tech will collaborate with EPA on the method and level of effort to be expended to evaluate the data before using it. Additional methods that might be used to determine the quality of secondary data are the following:

- Verifying values and extracting statements of data quality from the raw data, metadata, or original final report
- Comparing data to a checklist of required factors (e.g., analyzed by an approved laboratory, used a specific method, met specified DQOs, validated)

If it is determined that such searches are not necessary or that no quality requirements exist or can be established, but the data must be used in the task, Tetra Tech will add a disclaimer to the deliverable indicating that the quality of the secondary data is unknown.

4.4 Data Management (B10)

The Tetra Tech modeling team will not conduct sampling (primary data collection) for this project. Secondary data collected as part of this task will be maintained as hardcopy only, both hardcopy and electronic, or electronic only, depending on their nature.

Key secondary data have been compiled as part of the ongoing Lower Guyandotte River watershed TMDL modeling effort from a variety of sources into a common database (Microsoft Excel). The database will be used to support the TMDL model development.

The modeling software to be used for this project consists primarily of the MDAS model.

Tetra Tech will maintain and provide the final version of the model input, output, pre- and post-processed data and executables (including source codes on request) to EPA for archiving at the completion of the task. Electronic copies of the data, GIS, and other supporting documentation will be supplied with the final report. Tetra Tech will maintain copies in a task subdirectory (subject to regular system backups) and on disk for a maximum period of 6 years after project termination, unless otherwise directed by EPA.

Most work conducted by Tetra Tech for this task requires the maintenance of computer resources. Tetra Tech's computers are either covered by on-site service agreements or serviced by in-house specialists. When a problem with a microcomputer occurs, in-house computer specialists diagnose the problem and correct it if possible. When outside assistance is necessary, the computer specialists call the appropriate vendor. For other computer equipment requiring outside repair and not covered by a service contract, local computer service companies are used on a time-and-materials basis. Routine maintenance of microcomputers is performed by in-house computer specialists. Electric power to each microcomputer flows through a surge suppressor to protect electronic components from potentially damaging voltage spikes. All computer users have been instructed on the importance of routinely archiving work assignment data files from hard drive to compact disc or server storage. The office network server is backed up on tape nightly during the week. Screening for viruses on electronic files loaded on microcomputers or the network is standard company policy. Automated screening systems have been placed on all Tetra Tech computer systems and are updated regularly to ensure that viruses are identified and destroyed. Annual maintenance of software is performed to keep up with evolutionary changes in computer storage, media, and programs.

5.0 QA/QC PLAN AND ASSESSMENT

5.1 Assessment and Response Actions (C1)

The QA program under which model development will be performed includes surveillance and internal and external testing of the software application. The essential steps in the QA program are as follows:

- Identify and define the problem
- Assign responsibility for investigating the problem
- Investigate and determine the cause of the problem
- Assign and accept responsibility for implementing appropriate corrective action
- Establish the effectiveness of and implement the corrective action
- Verify that the corrective action has eliminated the problem

Many technical problems can be solved on the spot by the staff members involved; for example, by modifying the technical approach, correcting errors in input data, or correcting errors or deficiencies in documentation. Immediate corrective actions are part of normal operating procedures and are noted in records for the task. Problems not solved this way require formalized, long-term corrective action. If quality problems that require attention are identified, Tetra Tech will determine whether attaining acceptable quality requires short- or long-term actions. If a failure in an analytical system occurs (e.g., performance requirements are not met), the appropriate QC officer will be responsible for corrective action and will immediately inform the Tetra Tech Task TOL or QA Officer, as appropriate. Subsequent steps taken will depend on the nature and significance of the problem.

The Tetra Tech TOL (or designee) has primary responsibility for monitoring the activities of this task and identifying or confirming any quality problems. Significant quality problems will also be brought to the attention of the Tetra Tech QA officer, who will initiate the corrective action system described above, document the nature of the problem, and ensure that the recommended corrective action is carried out. The Tetra Tech QA officer has the authority to stop work if problems affecting data quality that will require extensive effort to resolve are identified.

Corrective actions could include the following:

- Reemphasizing to staff the task objectives, the limitations in scope, the need to adhere to the agreed-upon schedule and procedures, and the need to document QC and QA activities
- Securing additional commitment of staff time to devote to the task
- Retaining outside consultants to review problems in specialized technical areas
- Changing procedures

The assigned QC officer (or designee) will perform or oversee the following qualitative and quantitative assessments of model performance to ensure that models are performing the required tasks while meeting the quality objectives:

- Data acquisition assessments
- Secondary data quality assessments
- Model testing studies
- Model evaluations
- Internal peer reviews

5.1.1 Model Development Quality Assessment (B7, C1)

This QAPP and other supporting materials will be distributed to all personnel involved in the work assignment. The designated QC Officer will ensure that all tasks described in the work plan are carried out in accordance with the QAPP. Tetra Tech will review staff performance throughout each development phase to ensure adherence to task protocols.

Quality assessment is defined as the process by which QC is implemented in the model development task. All modelers will conform to the following guidelines:

- All modeling activities including data interpretation, load calculations, or other related computational activities are subject to audit or peer review. Thus, the modelers are instructed to maintain careful written and electronic records for all aspects of model development.
- If historical data are used, a written record on where the data were obtained and any information on their quality will be documented in the final report. A written record on where this information is on a computer or backup media will be maintained in the task files.
- If new theory is incorporated into the model framework, references for the theory and how it is implemented in any computer code will be documented.
- Any modified computer codes will be documented, including internal documentation (e.g., revision notes in the source code) and external documentation (e.g., user's guides and technical memoranda supplements).

The QC Officer will periodically conduct surveillance of each modeler's work. Modelers will be asked to provide verbal status reports of their work at periodic internal modeling work group meetings. The Tetra Tech TOL or his designee will make monthly detailed modeling documentation available to members of the modeling work group.

5.1.2 Software Development Quality Assessment

New software development is not anticipated for this project. If any such development is required, the QC officer (or designee) will conduct surveillance on software development activities to ensure that all tasks are carried out in accordance with the QAPP and satisfy user requirements. Staff performance will be reviewed throughout the project to ensure adherence to task procedures and protocols.

5.1.3 Surveillance of Project Activities

Internal peer reviews will be documented in the project file. Documentation will include the names, titles, and positions of the peer reviewers; their report findings; and the project management's documented responses to their findings.

Performance audits are quantitative checks on different segments of task activities. The Tetra Tech QC officer (or designee) will be responsible for overseeing work as it is performed and for periodically conducting internal assessments during the data entry and analysis phases of the task. The Tetra Tech TOL will perform surveillance activities throughout the duration of the task to ensure that management and technical aspects are being properly implemented according to the schedule and quality requirements specified in the data review and technical approach documentation. These surveillance activities will include assessing how task milestones are achieved and documented; corrective actions are implemented; budgets are adhered to; peer reviews are performed; data are managed; and whether computers, software, and data are acquired in a timely manner.

5.2 Reports to Management (C2)

The TOL (or designee) will provide monthly progress reports to EPA. As appropriate, these reports will inform EPA of the following:

- Adherence to project schedule and budget
- Deviations from approved QAPP, as determined from project assessment and oversight activities
- The impact of any deviations on model application quality and uncertainty
- The need for and results of response actions to correct any deviations
- Potential uncertainties in decisions based on model predictions and data
- Data quality assessment findings regarding model input data and model outputs

5.3 Reconciliation with User Requirements (D3)

Quality objectives for modeling are addressed in Section 2.4. Specific numeric acceptance criteria are not specified for the model; instead, appropriate uses of the model will be determined by the project team based on the types of decisions to be made, the model performance, and the available resources.

If the project team determines based on their best professional judgement and extensive experience that the quality of the model calibration is insufficient to address the principal study questions, based on overall performance, specific observations, technical difficulties, or data limitations, Tetra Tech will consult with EPA and other team members, as appropriate, as to whether the levels of uncertainty present in the models can allow user requirements to be met, and, if not, the actions needed to address the issue.

A detailed evaluation of model quality will be provided in the final modeling report.

6.0 QAPP IMPLEMENTATION

6.1 Project Organization (A4, A8)

The organizational aspects of the program provide the framework for conducting the necessary tasks. The organizational structure and function can also facilitate task performance and adherence to QC procedures and quality assurance (QA) requirements. Those who are leading the various technical phases of the project and those who are ultimately responsible for approving and accepting final products and deliverables fill the key task roles. The project organization chart, presented as Figure 5, includes relationships and lines of communication among all participants and data users. The responsibilities of those persons are described below.

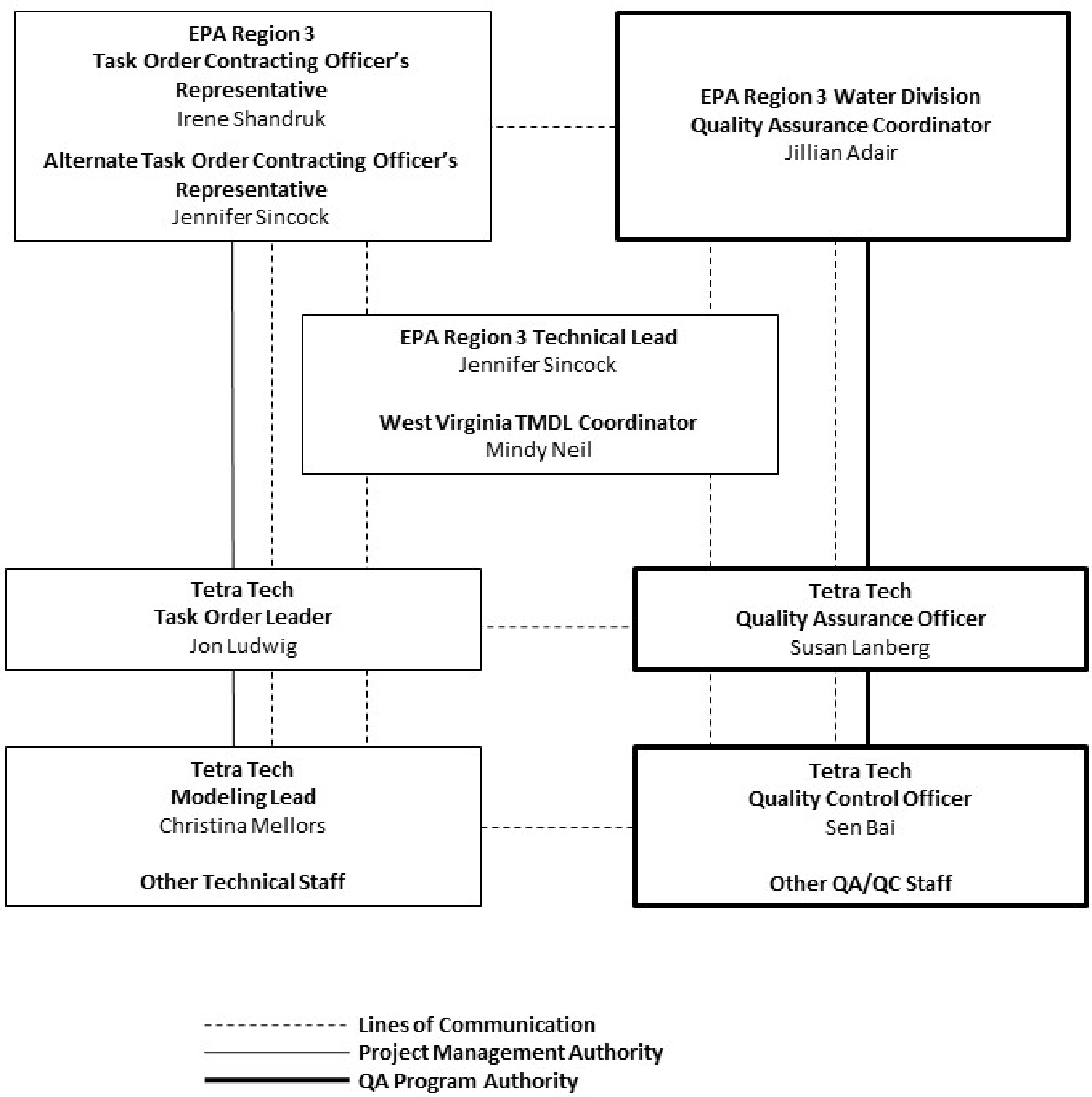

Figure 5. Organizational Chart

The EPA TOCOR, Ms. Irene Shandruk, and Alternate TOCOR, Ms. Jennifer Sincock, of EPA Region 3, will provide overall project and program oversight for this TO. They will review the QAPP, and other materials developed to support the project. They will also coordinate with contractors, reviewers, and others to ensure technical quality in all deliverables and adherence to the contract, as appropriate throughout the period of performance.

The EPA Region 3 Water Division Quality Assurance (QA) Coordinator is Ms. Jillian Adair. Her responsibilities include reviewing the project QAPP and participating in any Agency quality reviews of the project. Ultimately, Kia Long, the EPA Region 3 Quality Assurance Manager and Designated Approving Official will approve the final QAPP.

The Tetra Tech TOL, Mr. Jon Ludwig, will supervise the overall project. The specific responsibilities of the TOL include coordinating project assignments; maintaining the official approved QAPP; establishing priorities and schedules; ensuring completion of high-quality projects within established budgets and schedules; providing guidance and technical advice and evaluating the performance of those assigned to the project; implementing corrective actions; preparing or reviewing preparation of project deliverables, responses to EPA, action memos, and any other materials developed to support the project; and providing support to EPA in interacting with the project team, technical reviewers, and others to ensure that technical quality requirements are met in accordance with EPA's objectives. The TOL will facilitate interactions with task leads, WVDEP and EPA to ensure that project objectives are attained.

Tetra Tech modeling staff will be responsible for developing model input data sets, applying the model, comparing model results to observed data, calibrating the model, and writing documentation. Ms. Christina Mellors will lead the modeling efforts.

Other Tetra Tech technical staff will assist in data compilation and review, and aid in synthesizing results. Technical staff will implement the QA/quality control (QC) program, complete assigned work on schedule and with strict adherence to the established procedures, and complete required documentation.

The EPA Region 3 Technical Lead, Ms. Jennifer Sincock, and WVDEP's TMDL Manager, Ms. Mindy Neil, will be advisors and collaborators on model development and evaluation. They will participate in reviews of draft analyses, results, and reports and they will attend regular workgroup calls. They will defer to the EPA TOCOR for any changes to the project scope.

The Tetra Tech QA Officer is Ms. Susan Lanberg. Her primary responsibilities are the following: providing support to the Tetra Tech TOL in preparing the QAPP, reviewing and approving the QAPP, and assisting with monitoring QC activities to determine conformance with QA/QC requirements.

The Tetra Tech QC Officer, Mr. Sen Bai, will provide primary daily oversight. A QC Officer is a technical staff member familiar with the project who has not done the original work. The QC Officer will be responsible for monitoring QC activities to determine conformance and evaluating and reviewing project deliverables. QC evaluations will include reviewing site-specific model equations and codes (when necessary), double-checking work as it is completed, and providing written documentation of those reviews to ensure that the standards set forth in the QAPP and in other planning documents are met or exceeded.

Other QA/QC staff, including technical reviewers and technical editors selected as needed, will provide review oversight on the content of the work products and ensure that the work products comply with EPA's specifications.

6.2 Adaptive Management

Any proposed changes to the project that depart from this QAPP will be documented in a memo sent by the QA Officer to the TOL, who will then submit the memo and the draft revised plan (plan sections, procedural descriptions, or amendments) to facilitate review and approval. Minor administrative changes with regard to EPA or Tetra Tech project management teams are generally documented in the form of a technical memorandum, rather than issuing a full plan revision. The Tetra Tech TOL and EPA TOCOR will maintain and distribute the memo along with the approved, revised, and amended plans to all project staff as appropriate.

6.3 Record Keeping and Archiving (A9)

Thorough documentation of all modeling activities is necessary to be able to effectively interpret the results. All records and documents relevant to the application, including electronic versions of data and input data sets, will be maintained at Tetra Tech's offices in the central file. The central repository for the modeling work will be Tetra Tech's Fairfax, Virginia, office. Tetra Tech will deliver a copy of the records and documents in the central file to EPA at the end of the task. Unless other arrangements are made, records will be maintained at Tetra Tech's offices for a minimum of 5 years after task completion.

The Tetra Tech TOL and designees will maintain files, as appropriate, as repositories for information and data used in models and for preparing reports and documents during the task. Electronic project files are maintained on network computers and are backed up weekly. The Tetra Tech TOL will supervise the use of materials in the central files. The following information will be included in the hard copy or electronic task files in the central file:

- Any reports and documents prepared
- Contract and task order information
- QAPP and draft and final versions of requirements and design documents
- Electronic copies of models
- Results of technical reviews, internal and external design tests, quality assessments of output data, and audits
- Documentation of response actions during the task to correct problems
- Input and test data sets

- Communications (memoranda, internal notes, telephone conversation records, letters, meeting minutes, and all written correspondence among the task team personnel, suppliers, or others)
- Studies, reports, documents, and newspaper articles pertaining to the task
- Special data compilations

Records of receipt with information on source and description of documentation will be filed along with the original data sheets and files to ensure traceability. Records of actions and subsequent findings will be kept during additional data processing.

All data files, source codes, and executable versions of the computer software will be retained for internal peer review, auditing, or post-task reuse in the electronic task files in the administrative record. These materials include the following:

- Versions of the source and executable code used
- Databases used for model input, as necessary
- Key assumptions
- Documentation of the model code and verification testing for newly developed codes or modifications to the existing model

The Tetra Tech modeling QC Officer and other experienced technical staff will review the materials listed above during internal peer review of modified existing model or new codes or models. The modeling QC officer will perform QC checks on any modifications to the source code used in the design process. All new input and output files, together with existing files, records, codes, and data sets, will be saved for inspection and possible reuse.

Any changes in this QAPP required during the study will be documented in a memo sent by Tetra Tech's QA Officer to each person on the distribution list following approval by the appropriate persons. The memo will be attached to the revised QAPP.

All methods, assumptions, etc. will be documented in a final memorandum detailing the modeling process and conclusions, as required by the task order.

6.4 Staff Qualifications (A8)

Tetra Tech staff members involved in developing model input data sets and model application have experience in numerical modeling gained through their work on numerous similar projects. The Tetra Tech TOL, Mr. Jon Ludwig, will oversee the project and provide guidance to the modeling lead. He has 17 years of experience in managing WVDEP TMDL contracts and providing technical and innovative solutions. The TOL will ensure strict adherence to the project protocols.

The Tetra Tech TOL will oversee the project team in its execution of key project objectives. Ms. Christina Mellors, the Modeling Lead, and Mr. Sen Bai, the QC Officer will primarily assist the TOL. Ms. Mellors provides technical support to federal and state clients in the areas of watershed modeling, water quality assessment and management, and TMDL development. She has experience with MDAS, and she is currently serving as technical lead for the development of several West Virginia TMDLs for WVDEP. Mr. Sen Bai is an environmental engineer providing 18 years of technical support to federal, state, and municipal clients in the areas of water quality/sediment transport modeling, watershed modeling, hydrodynamic modeling, watershed management, point and nonpoint source pollution characterization and assessment, TMDL development and implementation.

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